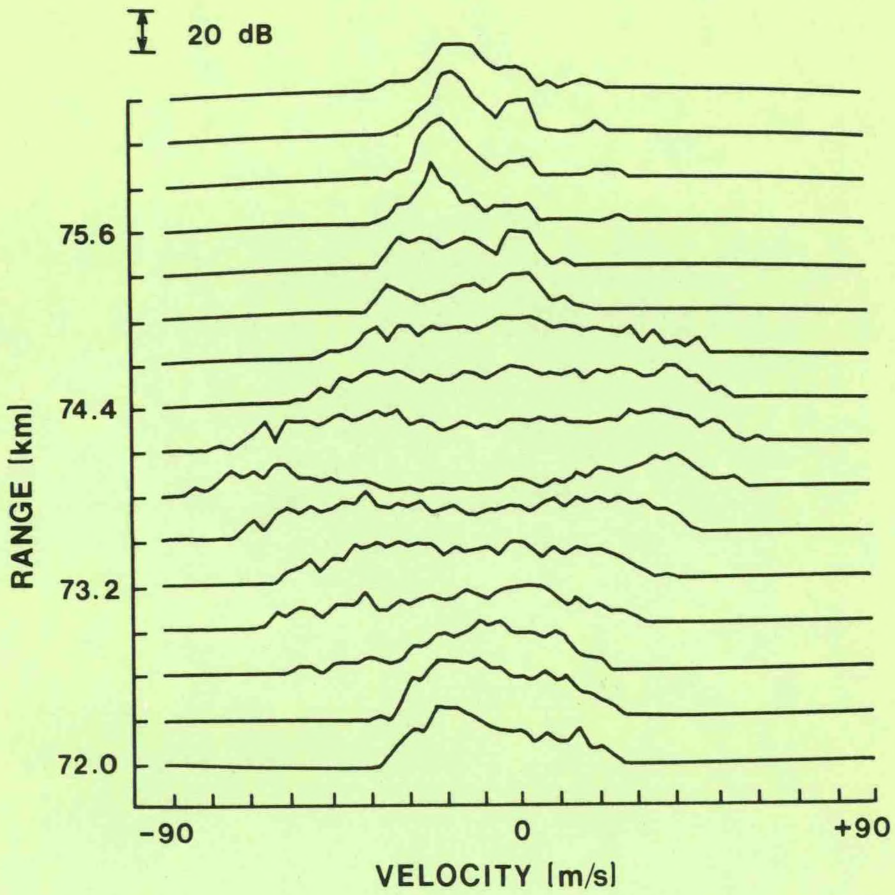
National Severe Storms Laboratory

ANNUAL REPORT FY-81



Doppler Spectra through an Intense Tornado

UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Environmental Research Laboratories

COVER

Velocity spectra were obtained with Doppler radar from a large and very intense tornado that occurred near Binger, Oklahoma on May 22, 1981. Spectra represent velocities weighted by the reflectivities inside the radar resolution volume; spectra are from contiguous ranges spaced 300 m apart along a ray through the center of the tornado. The bimodal tornado spectral signature is evident at 73.8 km, where the visible funnel approximately filled the radar beam.

During this data collection the radar was especially configured to provide clear indications over the huge span of velocities characteristic of major tornadoes. The flat spectral plateau is 8 dB above noise. Maximum rotational speed deduced from spectra is 80 m s^{-1}, and the tornado diameter is 1 km.

The Binger tornado is discussed in more detail on page 6 and an alternate spectral display actually used to track this tornado is presented as Fig. 5.

NATIONAL SEVERE STORMS LABORATORY

ANNUAL REPORT - FISCAL YEAR 1981

October 1, 1980 - September 30, 1981

National Severe Storms Laboratory
1313 Halley Circle
Norman, Oklahoma 73069
December 1981

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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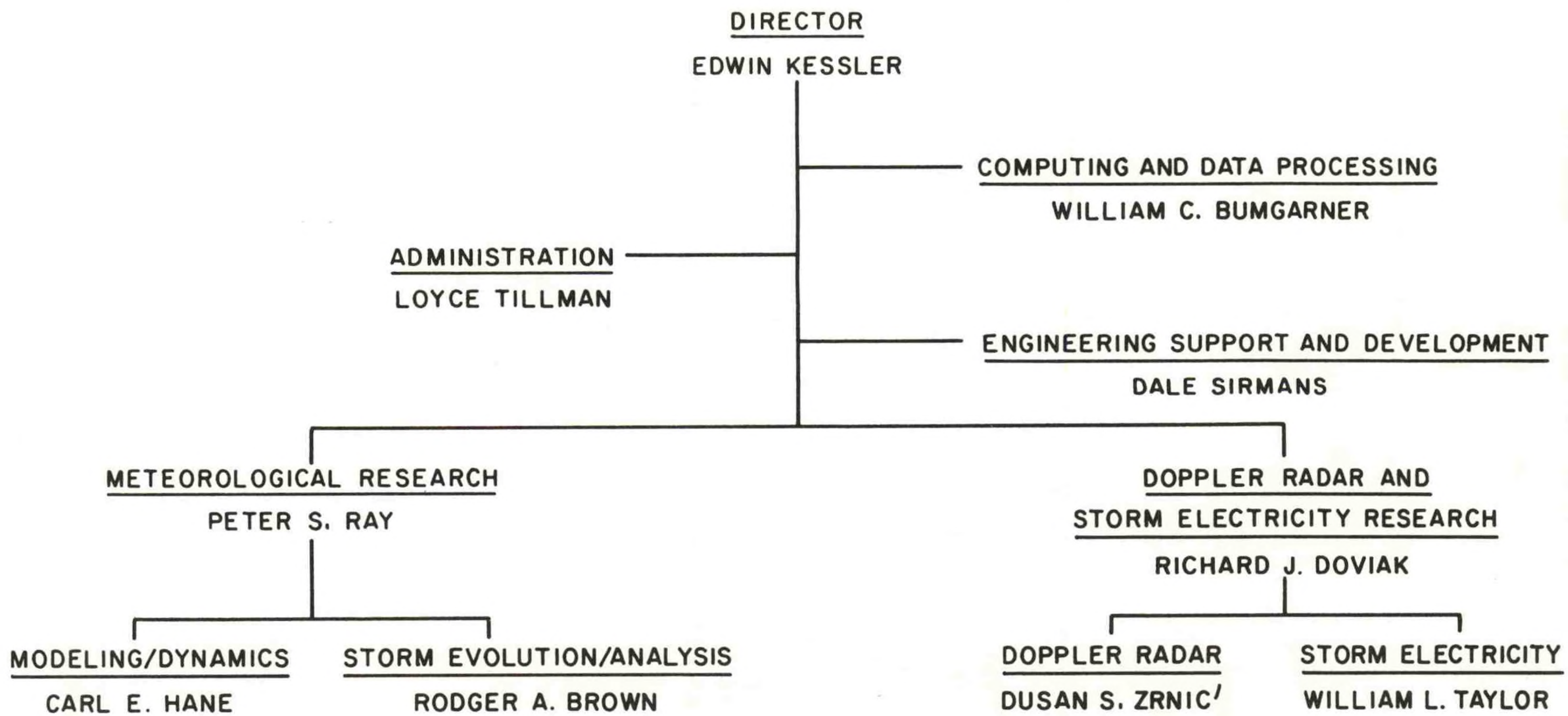
NATIONAL SEVERE STORMS LABORATORY

ORGANIZATIONAL CHART



As of September 30, 1981

NATIONAL SEVERE STORMS LABORATORY

PERSONNEL STATISTICS

FY-81

October 1, 1980 - September 30, 1981

	October 1, 1980		September 30, 1981	
	Full-time	Part-time	Full-time	Part-time
Professional	25	1	27	1
Technical	9	2	9	2
Clerical	6	5	6	3
TOTAL	40	8	42*	6

Number of Full-time
holding Doctoral Degrees - 12

During FY-81, recognition in the form of Promotions and various awards for exemplary performance were awarded to 24 of the above staff.

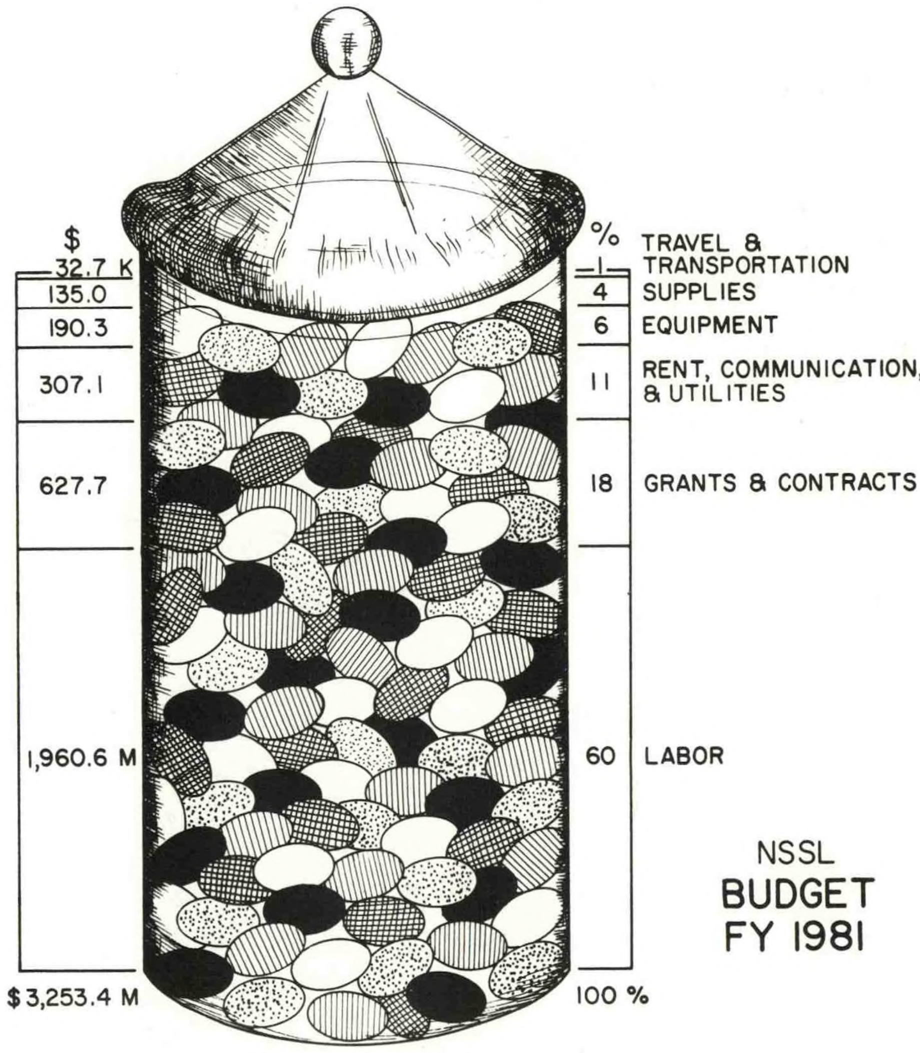
In addition to the above, the laboratory employs 14 students at The University of Oklahoma having assignments with NSSL staff who are Adjunct Professors at O.U. The Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) employs nine Graduate Research Assistants, two Computer Programmers, one Draftsperson, and a part-time Secretary supported by NSSL.

*Includes two National Research Council Post Doctoral Fellows.

NATIONAL SEVERE STORMS LABORATORY

FY 1981 Budget and Funding

NOAA Operations Research and Facilities		$2,380,400
NOAA Management Fund		385,000
Other Agencies:		
Federal Aviation Administration	- 345.6*	
National Aeronautics and Space Administration	- 135.0	
U.S. Department of Energy	- 8.0	
Total Other Agencies	-	488,600
GRAND TOTAL		$3,254,000



*In addition, NSSL acted as FAA's agent in the allocation of $200K which supported work in other offices supportive of the NEXRAD program.

PROGRAM AREAS

NATIONAL SEVERE STORMS LABORATORY

Edwin Kessler, Director

INTRODUCTION

This is an annual report on activities of the National Severe Storms Laboratory, one of NOAA's Environmental Research Laboratories, located in Norman, Oklahoma. Descriptions are given of the various activities with background for perspective, discussions of recent results, and plans for the near future.

The National Severe Storms Laboratory 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, 66 pp), the NSSL mission has changed little over the years, but the areas of major thrust have changed considerably, in response to new technological developments, new scientific discoveries, and new expectations. The Laboratory studies severe storm circulations and dynamics, and investigates techniques for improved storm detection and prediction. From an early emphasis on use of aircraft for storm investigations related to problems of flight safety, the Laboratory has progressively given greater relative emphasis to development of Doppler radar and its applications and to studies of storm electricity, and the Laboratory has significantly supported operational agencies with technologies for better use of weather radar and improved safety of flight.

The Laboratory maintains a 50-station capability for digital recording of surface meteorological parameters, and maintains instrumentation on the tallest tower in the United States that is equipped for recording of boundary layer parameters. Two 10-cm Doppler radars on a 42 km baseline provide unique capabilities for recording atmospheric circulations in both precipitating weather systems and the optically clear boundary layer. A comprehensive range of instrumentation for recording of electrical parameters provides accurate mapping of lightning discharges with measurement of electrical parameters, so that distributions of wind, water and electric fields can all be recorded contemporaneously, and their interactions examined.

Through numerous relationships with other government agencies and universities, the National Severe Storms Laboratory constitutes a resource for severe storms data examined by researchers around the country, and overseas. With many partners, the Laboratory has moved from editing and archiving data collected during the large field program, SESAME 1979 (Severe Environmental Storms and Mesoscale Experiment), to analyses of these data and their application to improved understanding and prediction of severe storms, and to improved means for observing them. The national program to develop a network of Doppler radars for improved storm warning to the public, and for improved safety of flight, is reflected at NSSL in the Interim Operational Test Facility (IOTF)--an office of the NEXRAD Joint System Program Office in Washington, D.C. It is expected that a test facility will be established soon at NSSL, to aid evaluation of operational procedures and techniques proposed for use with the NEXRAD radar. Our special relationship with the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) at the University of Oklahoma is discussed in a separate section.

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 the major convective phenomena and the pre-storm atmosphere. Analysis and interpretation of storm flow fields expand our understanding of external and internal forcing, thermodynamics, cloud physics, and dynamics, which contribute to intense thunderstorms and their attendant phenomena. The group is divided into the Modeling and Dynamics Project led by Carl Hane and the Storm Evolution and Analysis Project led by Rodger Brown.

RECENT ACCOMPLISHMENTS

Theoretical Studies

Theory: In a new look at the vorticity equation in tensor form, Davies-Jones has found the traditional view of the convergence and tilting terms in the vertical vorticity equation to be misleading. By treating vorticity amplification as a kinematical initial value problem, he has been able to explain certain observed facets of tornadoes and their surrounding flow fields, and to present a scenario of the processes leading to the formation of major tornadoes. In short, it is hypothesized that the ultimate rotation source for large tornadoes is ambient horizontal vorticity, and that the rear flank downdraft is indirectly instrumental in lowering the tornado circulation to the surface.

Modeling: Squall lines of large horizontal extent often include an area of intense convection along the leading edge and a larger area to the rear with more uniform, but potentially heavy rainfall. A multi-scale analysis and numerical simulation of a squall line which occurred on 19 May 1977 is near completion. This study will provide an understanding of how the intense convection along the leading edge is maintained and how this convection interacts with the environment to produce and maintain the broader area of rain to the rear. Kessinger and colleagues, for the 12th Conference on Severe Local Storms, have included as one aspect of this study a comparison of squall line structure and evolution as determined from a two-dimensional numerical model simulation with velocity and reflectivity fields analyzed from multiple Doppler radar observations. This is illustrated in Fig. 1.

Interactive use of both Doppler radar analyses and numerical model simulations has proven valuable also in examining various features of a tornadic storm. Klemp et al. (1981) have utilized the complete and self-consistent* data set from a three-dimensional numerical simulation of the 20 May 1977 Del City storm along with the more complex fields identified in Doppler data from the same storm, to investigate general structure, air parcel trajectories, and vorticity distribution near the time of storm maturity. The storm evolution was detailed by Ray et al. (1981). Where the two approaches agree, the results of each can be viewed with

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*i.e., kinematical features are consistent with dynamical features.

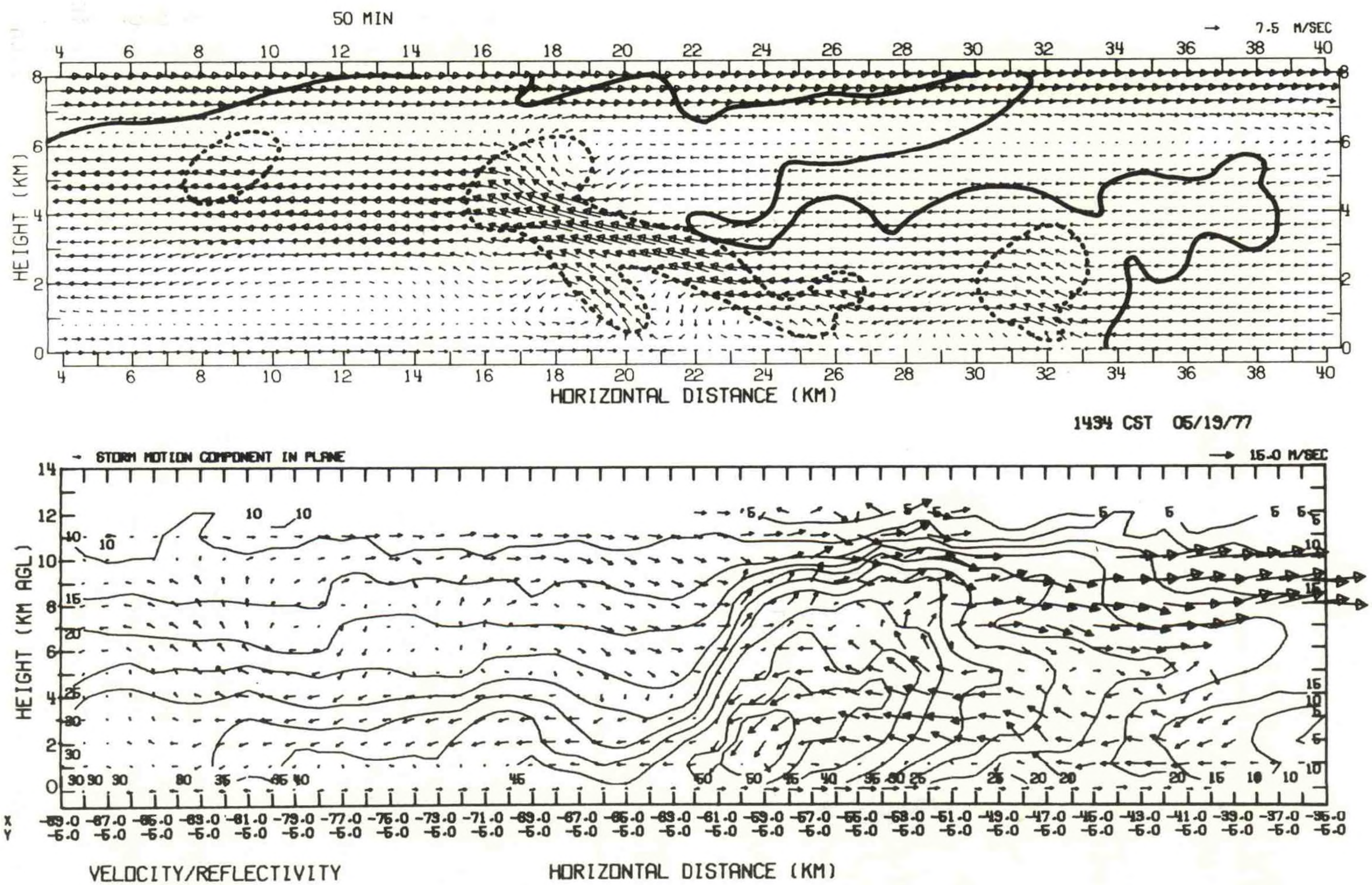

Figure 1. (a) Wind vectors, rainwater outline (solid), and cloud cores (dashed) from a 2-D cloud model utilizing environmental data from 19 May 1977. (b) Vertical cross section through the 19 May squall line showing wind vectors and reflectivity (dBZ). Compared to cross sections at other locations, intensity of circulation is of moderate intensity. Both model and observation show the existence of small areas of upward motion moving from east to west (right to left) above the westerly low-level outflow. These located in (a) at 22, 26, and 32 and in (b) at -42 and -48. The model results which include the advantage of fine time resolution, indicate that the small areas of upward motion originate at the gust front, travel westward over the outflow air interacting with other upward pulses near the ground which result from diverging downdrafts, and are a major factor in maintaining the intense convection 10-15 km west of the gust front (at this time).

greater confidence, while areas of disagreement allow focusing of efforts to improve the Doppler analyses or the model. As seen in the trajectory analysis presented in Fig. 2, there are many similarities in the flow fields.

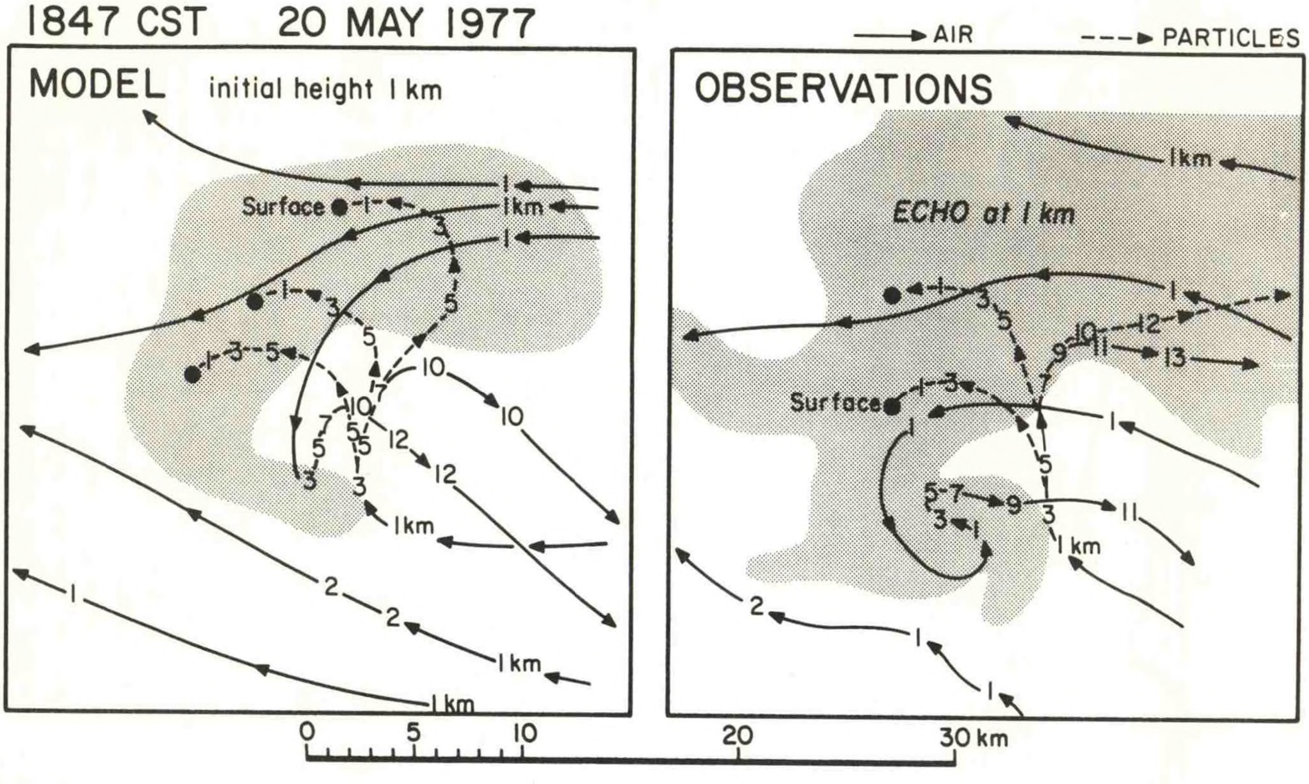

Figure 2. Model and observed trajectories of air parcels (solid lines) for air originating in the vicinity of 1 km. Heights along the trajectories are indicated. Precipitation trajectories (dashed lines) are included as selected locations along air parcel trajectories. The stippled areas encompass the rain-water field in the model panel and the 30 dBZ reflectivity contour in the panel utilizing observed data.

We would like to have the kinematical conformity between observations and model represented in Fig. 2, matched in the fields of thermodynamic variables. A practical application of comprehensive thermodynamic data lies in accurate initialization of numerical experiments. In an effort to derive detailed thermodynamic information from Doppler radar observations, a new approach to numerical modeling is being developed. Usually, numerical models in meteorology start from a perturbed initial state with precisely defined fields of temperature and pressure and, via a marching process, define development of fields of temperature, pressure, moisture, and wind. Complementary models are being developed and used by Hane et al. (1981) to recover the temperature and pressure distributions from observations on wind and moisture. As illustrated by Fig. 1 in our Annual Report for

FY-80, gratifying results have been obtained, and Dr. Hane is proceeding to adapt the method to use of wind and reflectivity fields derived from Doppler radar.

Observational Studies

In some cases, we can learn much about weather forecasting in the United States through carefully documented situations elsewhere. For example, as part of the international Alpine Experiment (ALPEX), McGinley has studied cyclogenesis in the lee of the Alps. Similar processes in the lee of the Rocky Mountains are believed to lead to severe storm outbreaks in the Southern Plains. The analysis indicates that lee cyclogenesis is a multi-stage process including a shallow terrain-induced barotropic phase (i.e., a phase determined by inertial properties of the initial flow fields), a rapid development phase where baroclinic processes (i.e., effects of temperature contrasts) are added and a mature stage in which the storm system is dominated by baroclinic processes. A critically important effect of the mountain range is the increase in strength of the zone of temperature contrast as it passes over the ridge. Responding secondary flow in the lee of the mountains consists of upward motion at middle levels superimposed over descending air at low levels on the mountain slope. Such vertical stretching produces a dynamical response which appears as increased cyclone strength.

The disposition of forces which drive convection has been indicated by an analysis of Bradberry (1981) of a squall line that passed through the NSSL surface and rawinsonde mesonetworks on 26 April 1969. A composite cross-section normal to the squall line reveals a mesoscale descent-ascent doublet in the vertical motion field. Descent was centered about 10 km ahead and ascent about 5 km behind the leading edge of the squall line. The downdraft appeared to be driven by evaporative cooling from the tops of the convective clouds; the updraft seemed to be driven mainly by condensational heating. This and other cases suggest that the doublet of mesoscale vertical motions may be a distinguishing feature of large convective storm systems in their mature stages of development.

Over the shorter time intervals of an hour or two, Weaver and Nelson in a forthcoming paper have documented the role that thunderstorm-produced gust fronts can play in the production of new severe storm activity. When the gust front from a storm intersected the gust front remaining from an earlier storm, the portion of the storm near the intersection experienced explosive growth with the subsequent production of a weak tornado. As has been shown by other investigators, the pre-existing gust front is sometimes evident in satellite pictures, and enhancement of approaching storms can then be forecast with more than usual confidence.

Tornadoes: The NSSL Tornado Intercept Project (TIP), in conjunction with intercept teams from the Universities of Oklahoma and Mississippi, had a very successful data collection period during the 1981 spring season. TIP aims to document the life cycles and the evolutionary characteristics of tornadoes and their parent storms with the aid of visual and photographic data. TIP research from 1972 through 1979 is summarized by Lee et al. (1981). On 17 and 22 May 1981, a total of nine tornadoes were photographed. Several of the movies are suitable for determining tornado wind speeds. Three tornadoes observed on 17 May were filmed with the "Vonnegut camera" (records lightning flashes on the audio track of a super-8mm movie camera); these indicated that there was little lightning near the tornadoes.

To document better the rear environment of a tornado, NSSL assisted the University of Oklahoma and Wave Propagation Laboratory in deployment of an instrumented package (TOTO--totable tornado observatory) in front of advancing tornadoes.

Data were obtained within 1 km of two tornadoes on 22 May and obtained beneath a wall cloud (without a tornado) on 17 May. This instrument package and the objects of its study are illustrated in Fig. 3.

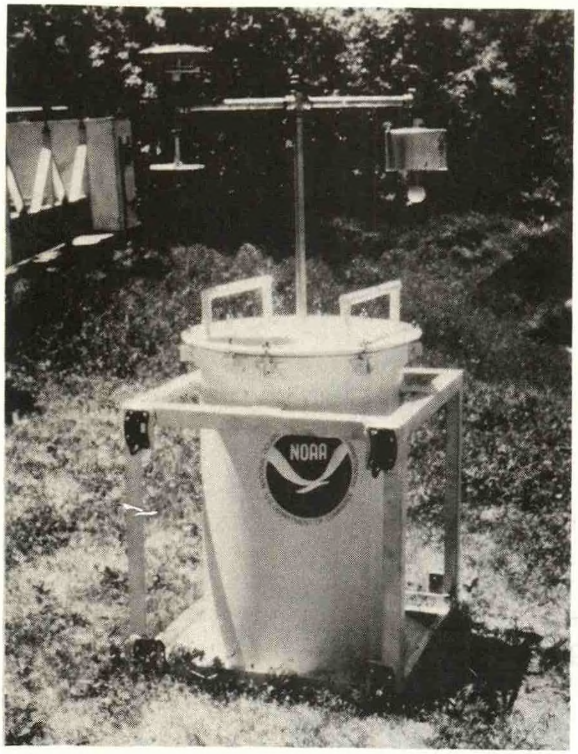

Figure 3. Totable Tornado Observatory (TOTO) developed by A. J. Bedard, Jr., of the Wave Propagation Laboratory. Sensors located on the cross-arm measure temperature, pressure, wind speed and direction, and corona discharge. The cylindrical container, that forms the stable base of the 400 pound device, houses the electronics, chart recorders and battery. Photo courtesy of Howard Bluestein.

The largest tornado on 22 May was up to 2 km wide at cloud base. It started near Binger, Oklahoma, and was on the ground for 24 km as it moved east-northeastward. Doppler velocity and reflectivity signatures associated with the tornado extended to the unusual height of 13 km (storm top was 14 km). Maximum tornado speeds of 90 m s^{-1} (relative to ground) were apparent in Doppler velocity spectra measured by the special fast pulse repetition transmitter with the Norman Doppler radar. Preliminary results were presented at the 12th Conference on Severe Local Storms.

Severe Storms: Data collected during the spring program help us to understand how severe storms form, how they evolve, and how the mesocyclones in which tornadoes are initiated develop. In all mesocyclone data collected with Doppler radars from 1971 through 1977, Burgess and colleagues found that the average radius of identified mesocyclone cores in single Doppler data (solid rotation analog) is 5 km, peak core tangential velocity is 23 m s^{-1}, and during the mature stage the mesocyclone extends from the ground to a height of 9 km in the storm. Two-thirds of the mesocyclones that reach the mature stage produce a tornado. The mesocyclone radar data indicate that mesocyclones with only one core during their lifetime (75% of the cases) exist for about 1.5 hours, whereas the remaining 25% with multiple and sequential cores last an average of 3.0 hours. We postulate that the sequential cores--which appear at 45 min. intervals--reflect a gust front occlusion process wherein the old updraft and associated vorticity concentration mechanism becomes cut off from the moist inflow at low levels and new updraft forms at the new point of occlusion. In his study of the Del City tornadic mesocyclone based on Doppler radar data, Brandes (1981) investigated details of the occlusion process. It is schematically shown in Fig. 4.

Hail: Techniques intended to suppress hail are used operationally in various parts of the world in an attempt to save crops from hail damage. However, no such federally sponsored operations exist in the United States because of lack of evidence that they are effective, and because we do not know enough about basic hail growth processes in severe storms to design reasonable suppression procedures. Part of the NSSL research effort--in conjunction with the National Center for Atmospheric Research and the University of Oklahoma--has been to try to understand hailstone growth. We combine growth characteristics revealed by the structure of collected hailstones with a numerical hail growth model that incorporates wind fields derived by Doppler radar and environmental thermodynamic parameters (Nelson, 1980).

Most severe hailstorms occur with supercells, which are large singular entities, contrasting to the multiple cellular characteristics of most thunderstorms. Nelson and Knight found hailstones with similar embryos (core region 0.5 to 1.0-cm in diameter) over a distance of 100 km and a time period of 1.5 hours beneath a supercell storm on 17 May 1980. This finding suggests that neither small scale nor short-lived storm flow features affect hailstone embryo formation. However, the outer crystalline structure of two hailstones collected 7 km apart at the same time showed marked differences. One stone apparently experienced a wetter and warmer growth regime than the other. This indicates that hailstones in supercell storms are not necessarily produced along similar growth trajectories, contrary to a recent hypotheses. A numerical hail-growth model indicates that density differences produce the most important changes in the early growth stages. Although all the hailstones grow in the same portions of the updraft, their trajectories differ significantly. There apparently are significant small-scale variations in growth trajectories that must be understood before hail growth in supercell storms can be explained adequately.

GENERAL STUDIES

Ray et al. (1980) compared single and multiple Doppler radar analyses in severe storms to evaluate various techniques for deducing storm structure. They ranked current practices in order of their use of information and how they performed against the most sophisticated analysis. According to that premise, with a variational analysis presumed to reproduce the real fields most faithfully, the ranking was in the same order as the degree of information processed.

A number of the Group members participated in a workshop on multiple Doppler radar at the National Center for Atmospheric Research. Among the workshop summary articles where those by Ray et al. (1980) and Moninger and Nelson (1980).

Brown et al. (1981) have described basic features of the Multiple Radar Analysis (RADAN) System, which was designed to accommodate inevitable future changes.

Using colocated 5-cm and 10-cm wavelength Doppler radars, Allen et al. (1981) documented the disappearance of the Wichita Falls tornadic storm from the 5-cm

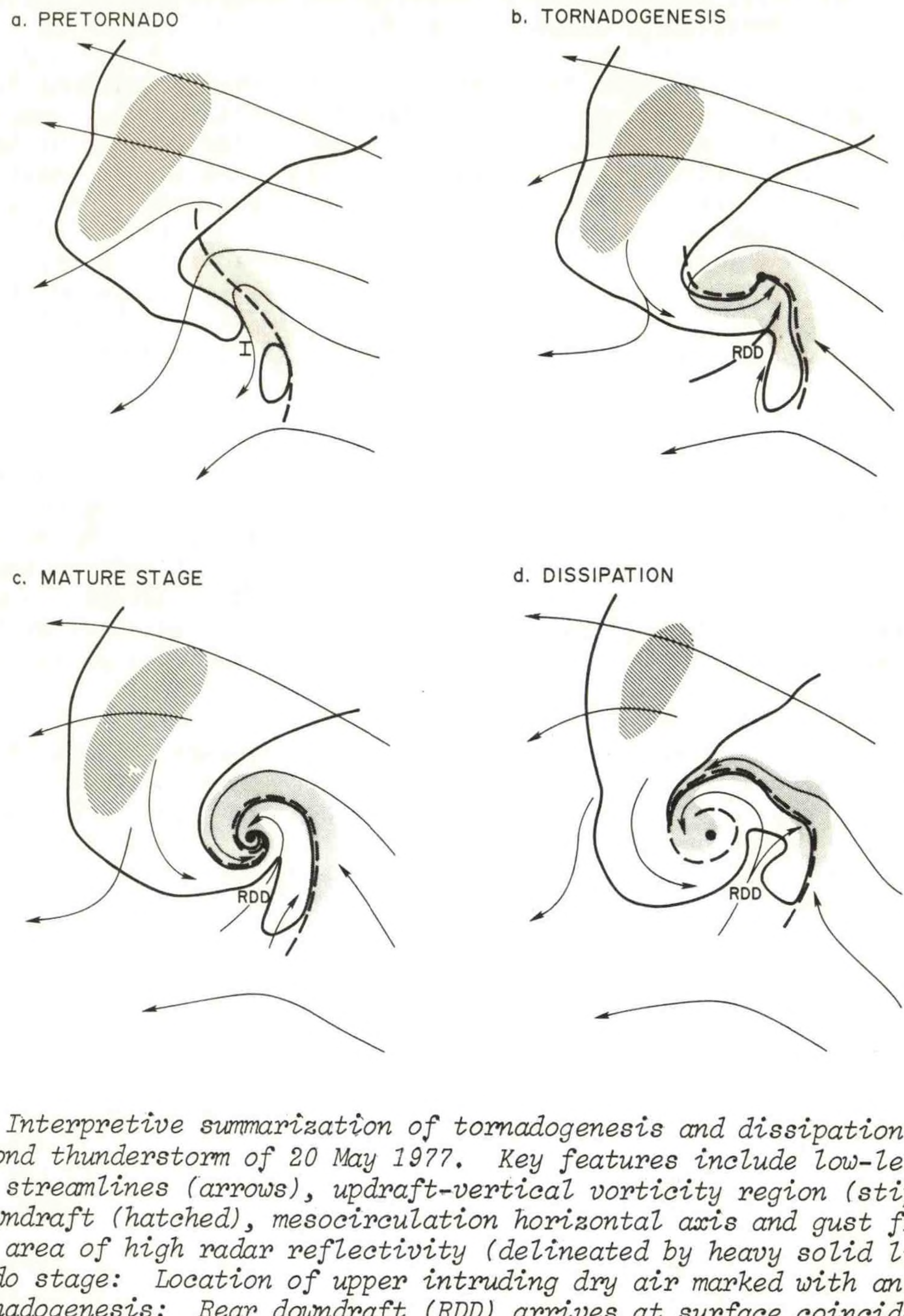

Figure 4. Interpretive summarization of tornadogenesis and dissipation in Del City-Edmond thunderstorm of 20 May 1977. Key features include low-level storm relative streamlines (arrows), updraft-vertical vorticity region (stippled), rainy downdraft (hatched), mesocirculation horizontal axis and gust front (dashed), and area of high radar reflectivity (delineated by heavy solid line). (a) Pretornado stage: Location of upper intruding dry air marked with an I. (b) Tornadogenesis: Rear downdraft (RDD) arrives at surface coincident with perturbation of updraft-vorticity zone and with intensification of low-level mesocirculation. Tornadogenesis (black dot) occurs to the left of the intruding flow. (c) Mature stage: Roll-up of mesocirculation axis and precipitation curtain (hook echo) continues about tornado. Mesoscale swirl flow at maximum intensity. (d) Dissipation: Choking of storm inflow and loss of both wind and reflectivity discontinuities. New updraft growth at gust front nose.

radar scope on 10 April 1979. Attenuation of the 5-cm signal by an intervening severe storm points out, once again, a serious inherent problem associated with the use of 5-cm radars for storm detection and warning.

During FY-81, Kessler completed the editorial work related to Volume One of a comprehensive documentary on thunderstorms, and the 206-page book was printed by the Government Printing Office for distribution to federal depository libraries and for sale to the public. Eighteen different authors contributed eight chapters on the thunderstorm in human affairs--specific topics include impacts of tornadoes and floods, thunderstorms in agriculture, forest management and aviation, wind effects on buildings, and the programs of thunderstorm prediction and of thunderstorm research in the United States.

Kessler has also been studying wind power with data from actual wind generators at three locations, the NSSL mesonetwork, and the meteorological record at Oklahoma City. Carter interfaced a current probe to the wind generator at Kessler's home to provide a continuous record of the output of the device on an Esterline Angus recorder. Wardius and Fredrickson of NSSL installed anemometers at heights of 31 ft. and 53 ft. on the 60 ft. tower supporting the generator so that the wind speed at these two levels can also be recorded. A small grant was received at NSSL from the Department of Energy to pay the salary of a CIMMS employee who will be engaged in study of the data collected on wind power generation.

EXPECTATIONS FOR FY-82

During FY-82, major efforts of the Meteorological Research Group will continue to emphasize analyses of multiple Doppler radar data on severe storms and establishment of relationships connecting the coevolving distributions of wind, temperature and hydrometeors in storms. In particular:

1. Theoretical and observational investigations of tornadogenesis and mesocyclone structure will continue. Studies of storms that occurred during SESAME on 2 May 1979 and 6 June 1979, and on 19 June 1980 will be completed. Each of these provides information on a different facet of storm evolution. We will also investigate a well-documented tornadic storm that occurred on 22 May 1981 near NSSL's Doppler radars and storm electricity measuring apparatus.

2. We will complete development of a numerical model for microphysical processes with parameterized formulations applicable to both warm and cold clouds and will use it in conjunction with observed data in selected storm cases. The promising thermodynamic retrieval method will be applied to one or more storm velocity data sets to clarify its utility as a diagnostic tool and to develop methods for initializing cloud models with real data.

3. Additional analysis and dynamical modeling of the 19 May 1977 squall line will be completed with insights into squall line dynamics on several scales. A hail-growth model will be used to assess, along with "ground truth," the size and shape of thunderstorm updrafts which are most favorable for hail growth.

4. Lee cyclogenesis near the Rocky Mountains will be examined in relation to dry line formation and subsequent severe storm development.

5. A study of temporal and spatial correlations for surface mesonetwork data pertaining to thunderstorm occurrences for the years 1973-1979 is expected to be completed. The correlations will be used to establish optimum weighting functions for objective analysis of mesonetwork data.

6. The comprehensive documentary on severe storms edited by Kessler should be completed. Volume Two will comprise 16 chapters on thunderstorm morphology and dynamics, and Volume Three will present 11 chapters on the acquisition and analysis of storm data.

7. Study of data on wind power generation should be substantially completed at the end of the fiscal year. We expect to assess wind power availability in relation to altitude and topography through much of Oklahoma, and we expect to characterize wind power variability over a wide range of spatial and temporal scales.

DOPPLER RADAR AND STORM ELECTRICITY RESEARCH (DRASER)

Richard J. Doviak, Group Leader

INTRODUCTION

This group was formerly named Advanced Techniques, but the new title is more descriptive of the research we pursue. Our Doppler Radar Group interprets atmospheric phenomena using the Doppler radar both for prestorm and stormy weather, and this group develops improved techniques to acquire and analyze observational data.

The Storm Electricity Group focuses on observations of lightning discharges and generally examines the distribution and development of electrical activity in thunderstorms. We seek to identify electrical interaction with other parameters, in particular the microphysical and kinematic processes which influence the development and distribution of water substance and which may support the production of severe thunderstorms and tornadoes.

RECENT ACCOMPLISHMENTS

Doppler Radar Data Collection Program

This spring's data collection effort was most intense in May when several tornadic storms developed in the vicinity of NSSL radars. The experimental procedures and objectives were similar to those outlined in the Spring 1980 Program Summary (Doviak, 1981a). One of the storms on May 22nd provides a unique data set from the birth of a storm to subsequent tornado formation. With the help of a polar spectrum display (Fig. 5), high-PRF time series data were collected from a maxi-tornado. This may allow a remote measurement of maximum wind speeds in this large tornado and better resolution of the tornado's kinematic structure (Zrnic' and Istok, 1980; Lee et al. 1981). Other very strong storm days were 9, 17, and 23 of May. Low-level wind data were obtained from the KTVY-TV meteorological tower and the LLWAS* system at Will Rogers International Airport at Oklahoma City, Oklahoma, on 17 and 22 May.

The NASA F-106 aircraft, instrumented to measure wind, turbulence and atmospheric electricity, participated in the Spring Program from 25 March to 24 April. While no direct lightning strikes were encountered, the sensing equipment was triggered by a number of nearby flashes, and moderate-to-severe turbulence was encountered on several flights.

An experiment with NASA's Marshall Space Flight Center began on 29 June when NASA's Convair 990 arrived at Tinker Air Force Base. The Convair 990 carried a Doppler lidar. The program invites studies of air flow in the boundary layer and in thunderstorm environments.

As part of a joint FAA-Air Transport Association and NOAA program, an experimental test of commercial prototype airborne Doppler radar began in mid-July. An FAA DC-9 based at the FAA Technical Center, Will Rogers International Airport, Oklahoma City, was made available to the project, and the necessary modifications were completed.

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*Low-level wind sounding alert system

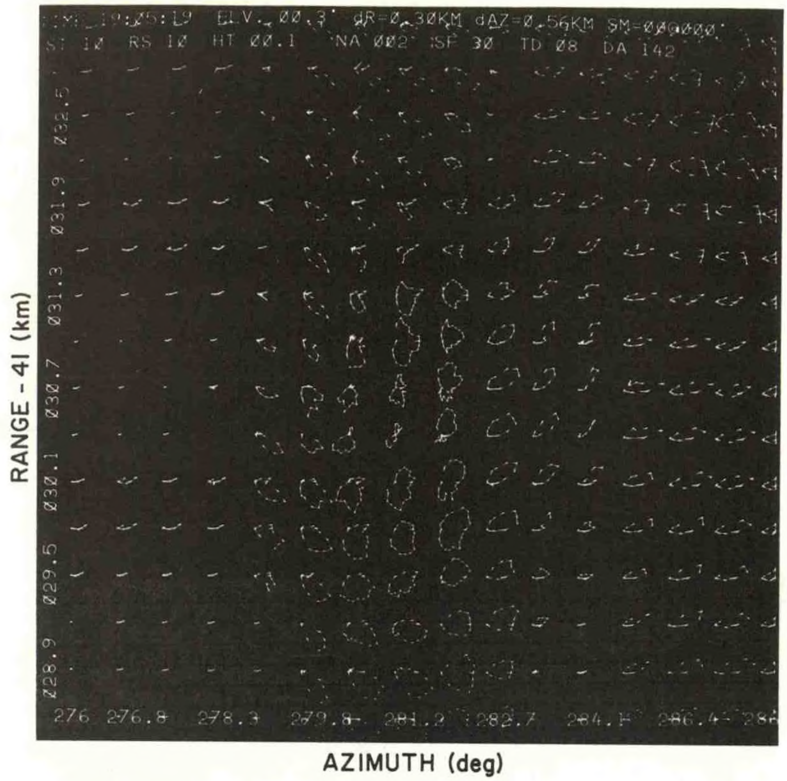

Figure 5. Doppler spectra in polar format displayed along azimuth (abscissa) and (ordinate) range. The separation of spectra in range is 300 m and in the azimuthal direction it is approximately 560 m. Each spectrum is plotted in a polar format with powers proportional to radii and velocities equal to the polar angle. Maximum unambiguous velocity of ±91 m s^{-1} is at ±180°. In this example the origin of the polar system corresponds to a power 8 dB above receiver noise. To obtain correct ranges, add 41 km to each indicated range.

Mapping Kinematic Wind Properties in the Prestorm Environment Using Doppler Radar

Computational algorithms (velocity volume processing, VVP, see 1980 Annual Report) using single Doppler radar have been used to map certain mesoscale (20-100 km) kinematic properties of the convective boundary layer (CBL) a few hours in advance of subsequent thunderstorm development (Doviak et al. 1980; Doviak, 1981b). Results have improved after sophisticated editing procedures were applied to the radial velocity fields for removing anomalous point target echoes (i.e., birds, aircraft). Maximum convergence and deformation were observed along a frontal zone, and their frontogenetical effect has been estimated. The horizontal wind field of Fig. 6 has been computed by assuming uniform wind in each analysis volume (40°x 0.8°x20 km). The results appear reasonable when compared to *in situ* rawinsondes, mesoscale surface and upper air analysis. The frontal surface can be resolved clearly from the wind field and its slope with height was measured. Although a local maximum of convergence was observed near an area where thunderstorms later

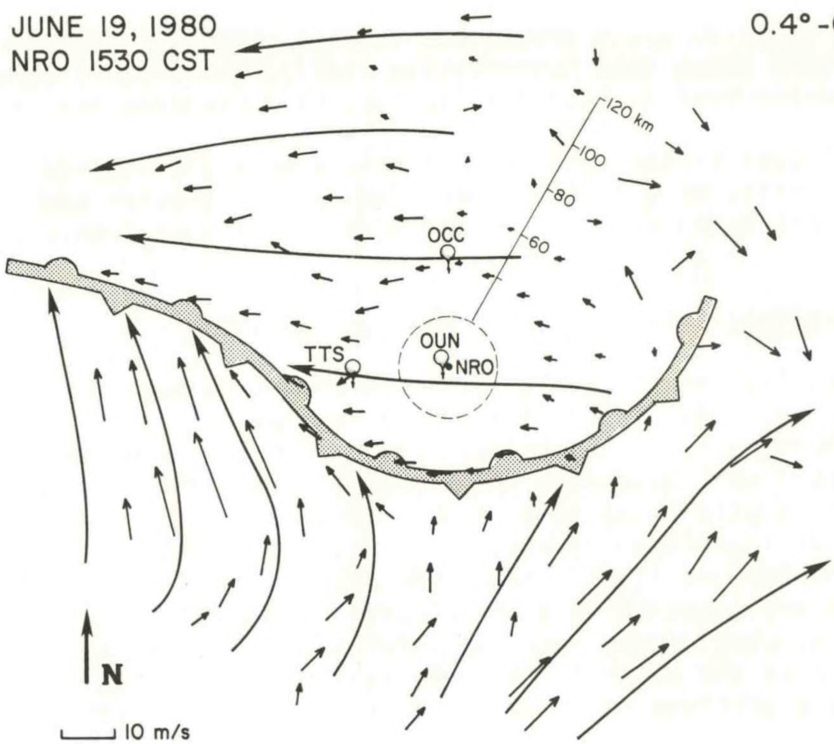

Figure 6. Vector winds derived from single Doppler velocity field for a clear air prestorm environment.

developed, the convergence was about one-fourth that necessary to initiate moist convection as estimated from parcel theory. However, the minimum resolvable scale for these convergence estimates are several times the actual shower scale.

Doppler Radar Observations of Momentum Flux in the Convective Boundary Layer

Dual Doppler radars were used to obtain momentum flux and turbulence intensities in the convective boundary layer. Such measurements are basic to understanding the generation and dissipation of atmospheric flows. Radar-measured horizontal turbulence compares well with aircraft data and reveals the presence of roll vortices. We observe that eddies larger than about 1 km transport momentum in the opposite direction to that by smaller scale eddies unresolved by the radar. Although this process goes counter to the popular assumption that turbulent mixing is analogous to molecular diffusion, it has been observed elsewhere. We also deduce a turbulent energy sink by wind shear in the upper portion of the boundary layer, similar to observations by others.

Turbulence Studies

Detection of thunderstorm turbulence and display of turbulence location offer significant improvement in flight safety and utilization of critical airspace (Lee, 1981; Zrnic' and Lee, 1981). NSSL studies have shown correspondence of turbulence and spectrum width trends and studies using NSSL Doppler radar and aircraft data have shown good (correlation coefficient = >0.8) agreement. Studies of view angle dependence to test the isotropy of turbulence are in progress.

Studies of gust fronts also include this view-angle dependence feature to determine the ability of a single radar (Doppler) to provide adequate coverage (i.e., significant data) on location and severity of gust fronts and other wind shear events.

Lifetimes and Vertical Scale Sizes of Weather Features

Studies on lifetimes of atmospheric features have been conducted in two phases (Zrnic' and Smythe, 1980). The first phase was based on visual interpretation of sequences of photographs of the reflectivity, velocity, and spectrum width fields corresponding to a well developed storm observed on April 24, 1980. Important features of the storm were found to be stable over a period of 10 minutes. The vertical scale size of significant features was found to be at least 1.5 km. The determination of feature lifetimes has been automated and a computer program based on time-delayed and space-shifted correlation is now available. Findings from this correlation study about decay rate and lifetime of selected storm features are in good agreement with the visually inferred values. These studies will help determine the scanning strategy of the weather radars near airports (Mahapatra and Zrnic', 1981).

Doppler Radar Echoes of Lightning

Digital time series data at 16 heights through two storms were collected at vertical incidence with a 10-cm Doppler radar (MacGorman et al. 1981). On several occasions during data collection, lightning echoes were observed as increased reflectivity on an oscilloscope display. Simultaneously, lightning signals from nearby electric field change antennas were recorded together with the radar echoes. Reflectivity, mean velocity and Doppler spectra were examined by means of time series analysis during and after lightning discharges. Spectra from locations where lightning occurred show peaks due to the motion of the lightning channel as it follows the air speed (Fig. 7). These peaks are considerably narrower than those due to precipitation. Besides indicating the vertical air velocity that can then be used to help estimate hydrometeor-size distribution, the lightning spectra provide a convenient means for estimating the radar cross-section of the channel. Subsequent to one discharge, a rapid change in the orientation of ice crystals seems to have occurred within the resolution volume.

Real-Time Processing and Display

A paper describing various radar waveform designs to mitigate Doppler radar ambiquities has been published (Doviak and Strauch, 1980). A new real-time computer for Doppler data signal processing arrived and software development of some algorithms began. A method to detect mesocyclones and shear lines automatically was programmed and is being tested. Preliminary results (Fig. 8) show agreement in the location and size of a mesocyclone determined by the algorithm and by a meteorologist.

Development of a display for Cimarron radar was accomplished, and hardware and software for improved display of data from the WSR-57 radar and from the IFF aircraft beacon system have been completed.

(a)

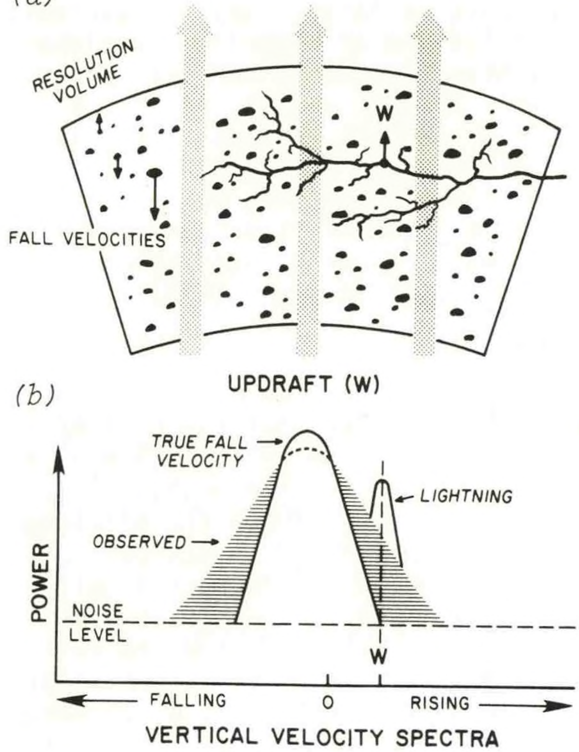

Figure 7a. Portion of a lightning flash and precipitation particles of various fall velocities imbedded in an updraft of speed W within the resolution volume of the upward looking Norman Doppler radar.

Figure 7b. The power spectra shown below depict the true fall velocity spectrum (solid curve) of the precipitation within the resolution volume and the observed spectrum (shaded curve). Due to signal processing effects and assumptions in the analysis, calculations of updraft velocity from the Doppler spectra can differ significantly from the true W. The actual updraft velocity can be determined from the peak of the lightning echo spectrum since the lightning is neutrally buoyant and moves with the updraft.

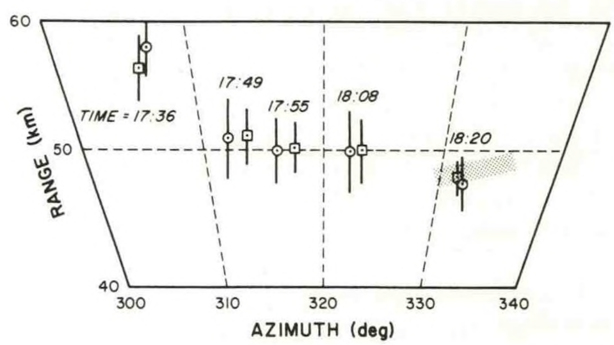

Figure 8. Azimuth versus range display of mesocyclones position and diameter. Bars with circles depict the diameter and position produced by the algorithm whereas bars with squares are values subjectively calculated from Doppler velocity fields. Maxi-tornado damage path is superposed.

Mean velocity estimators based on a small number of samples were studied. It is shown that Fast-Fourier transform estimators fare poorly when the ratio of signal-to-noise is low and/or when the spectrum width is large. Several variants of a vector pulse pair processor have been postulated and an algorithm developed for the resolution of phase angle ambiguity. We have identified a better processing algorithm than conventional processors at very low SNR values. A feasible approximation to the maximum entropy estimator is derived as well as a technique utilizing the maximization of the periodogram. It is found that a vector pulse pair processor operating with four lags for clear air observations and a single lag (pulse-pair mode) for storm observation may be a good way to estimate Doppler velocities over the entire gamut of weather phenomena. Spectral statistics for complex colored discrete time sequences have been derived (Zrnic', 1980).

Study of a Ground Clutter Filter

Study of the ground clutter at the Norman site indicates that its Doppler spectrum width, σ_c, is between 0.1 and 1 m s^{-1} with the mean value of 0.25 m s^{-1} at an antenna rotation rate of 10° s^{-1} (Zrnic' and Hamidi, 1981). The design of clutter filters is very much dependent on this width and for proper cancellation the passband cutoff velocity v_p must be larger or equal to 4.8 σ_c. Several canceling schemes were investigated, and the most efficient one is with a third order recursive filter. This filter achieves a 50 dB rejection in the stop band with total annihilation of DC. One dB ripple is in the pass band, and the ratio of pass band cutoff v_p to stop band cutoff v_s is about 3.5. The filter operates best in steady state, but it can also be made to operate in transient by properly initializing its memory elements. Expected attenuation after a clutter step is applied (Fig. 9) shows that initialization improves the performance by about 20 dB.

Book on Doppler Weather Radar

Drs. Doviak and Zrnic' have completed the first nine chapters of a forthcoming book Doppler Weather Radar. The book will have eleven chapters dealing with Doppler weather radar, its signals, and techniques to observe weather. We expect it to be published by Academic Press.

EXPECTATIONS FOR FY-82

Design of interfaces and development of programs for a real-time radar signal processor will be advanced. Composite display of hazardous weather will be developed.

Relationships between turbulence in storms and Doppler spectral moments will be examined further. Doppler spectrum width data will be collected by two radars so that aspect sensitivity of turbulence can be determined. Turbulence-generating mechanisms will be investigated, and gust fronts sensed by Doppler radar will be examined.

We expect to test the algorithm for automatic recognition of mesocyclones, shear lines and strong divergence, and data will be collected to determine predictability of rapid storm growth from the first echo.

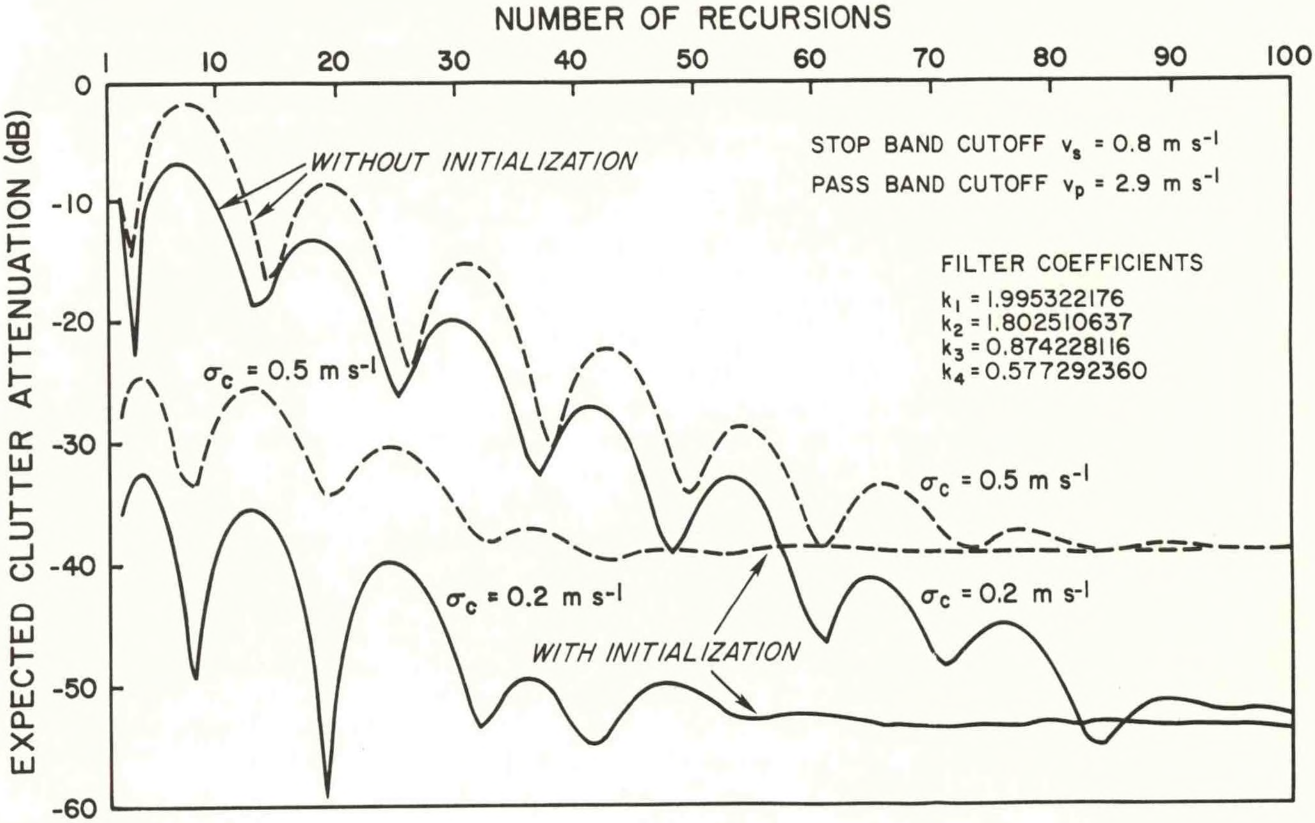

Figure 9. Expected attenuation after a step of clutter power is applied to the filter. Two clutter spectrum widths, $\sigma_c = 0.2$ m s^{-1} and $\sigma_c = 0.5$ m s^{-1} are considered for both the initialized and noninitialized filter.

Storm Electricity (William L. Taylor)

This program deals with many complex facets of lightning and other storm electricity parameters (Rust et al. 1981). Major objectives include: 1) evaluate storm electricity parameters as indicators of thunderstorm severity and gross features of precipitation and wind structure (Rust et al. 1981), 2) locate and track thunderstorms and determine lightning ground strike locations, 3) develop techniques to predict and warn for lightning hazards, 4) determine lightning characteristics for inputs into engineering criteria for lightning hazards and into models used in environmental and thunderstorm studies, 5) measure effects of electric fields and lightning on radar-derived meteorological parameters, and 6) devise new observational techniques.

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

Recent Results

The 1981 Spring Program at NSSL again placed a high priority on storm electricity observations. Data acquisition with the VHF lightning mapping sites colocated with NSSL's dual 10-cm wavelength Doppler radars and other storm electricity sensors at the Storm Electricity Building were closely coordinated. Simultaneous observations were made of numerous severe storms and several tornadic storms within the dual mapping areas. A mobile laboratory was used to record electrical activity in many severe storms and near several tornadoes in the Oklahoma, North Texas, and Texas Panhandle regions (Arnold and Rust, 1980). A combination of sensors, including the L-band radar and the VHF mapping units, was also used to identify regions of lightning activity for guidance information to a NASA F-106 which penetrated storms to measure turbulence and lightning strikes to the aircraft. The Norman Doppler radar was used in a vertically pointing mode to determine the precipitation size distribution and the true vertical wind speed by using the lightning channel as a tracer.

Intracloud lightning development continues to present a very complex picture as revealed by VHF mapping data. Long discharges, some longer than 50 km, generally progress at speeds between 5×10^4 and 3×10^5 m s^{-1}. Many of these long discharges do not appear to be a single interconnected flow of current made up of many channels, but may be composed of several closely related discharges. To further pursue this phenomenon and support other experiments requiring lightning location, the VHF mapping instrumentation at Norman was modified to accommodate switching into a vertical looking mode to observe lightning overhead.

Lightning echoes from a 23-cm wavelength (L-band) radar were simultaneously observed with the VHF mapping discharges (Taylor and Mazur, 1980), not only to track lightning in the mesocyclone region of storms, but also to compare and correlate the two methods of observing lightning. We are comparing locations of VHF impulse sources with lightning echo target positions to obtain evidence that VHF impulse sources lie along the highly ionized channels produced by lightning processes. A computer tabulation of lightning echoes from the L-band radar is presented in Fig. 10. This shows symbolically coded reflectivity that is threshold detected to eliminate precipitation echoes. Lightning occurring within the radar beam produces enhanced reflectivity that changes in time as a function of range. Note the three reflectivity regions marked A, B, and C. At first glance these seem to be separated in time and range with no apparent physical connection.

The VHF space-time mapping of this lightning flash is shown in Fig. 11 with the radar beam superimposed. The VHF mapping system begins to respond to the flash at a range of about 75 km as it approaches Norman. The dark meandering line is the centroid path of clusters of VHF impulse source locations as a function of time which is given each 20 ms as cross ties on the lightning track. The lightning channel was longer than 100 km within the VHF dual mapping area. Regions A, B, and C in Fig. 10 are also designated here and clearly show that lightning echoes are observed when lightning activity crosses the radar beam.

The principal characteristics of the L-band lightning echoes, in terms of range and time fluctuations, are consistent with the lightning structure obtained from VHF mapping data. The rise time of the lightning radar echo is compatible with channel propagation through the beam. Lightning progression speeds from radar data are likely to be underestimated for lightning progressing along the beam

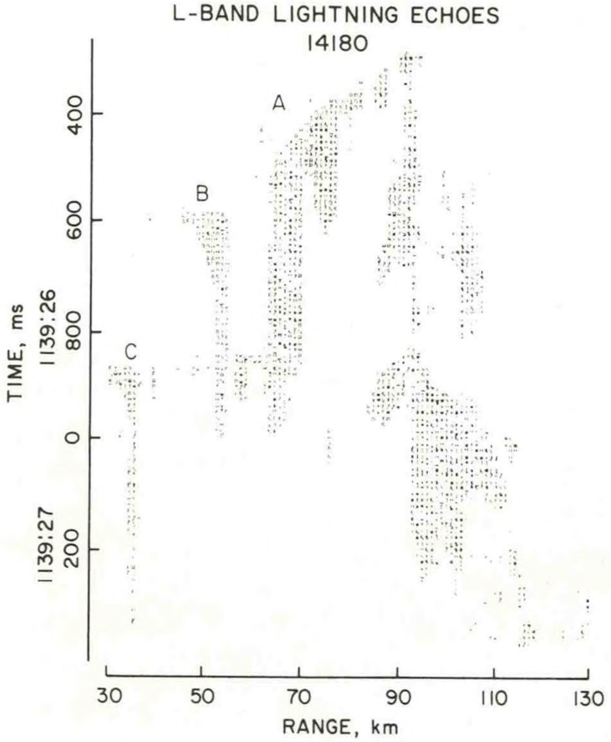

Figure 10. L-Band Lightning Echoes

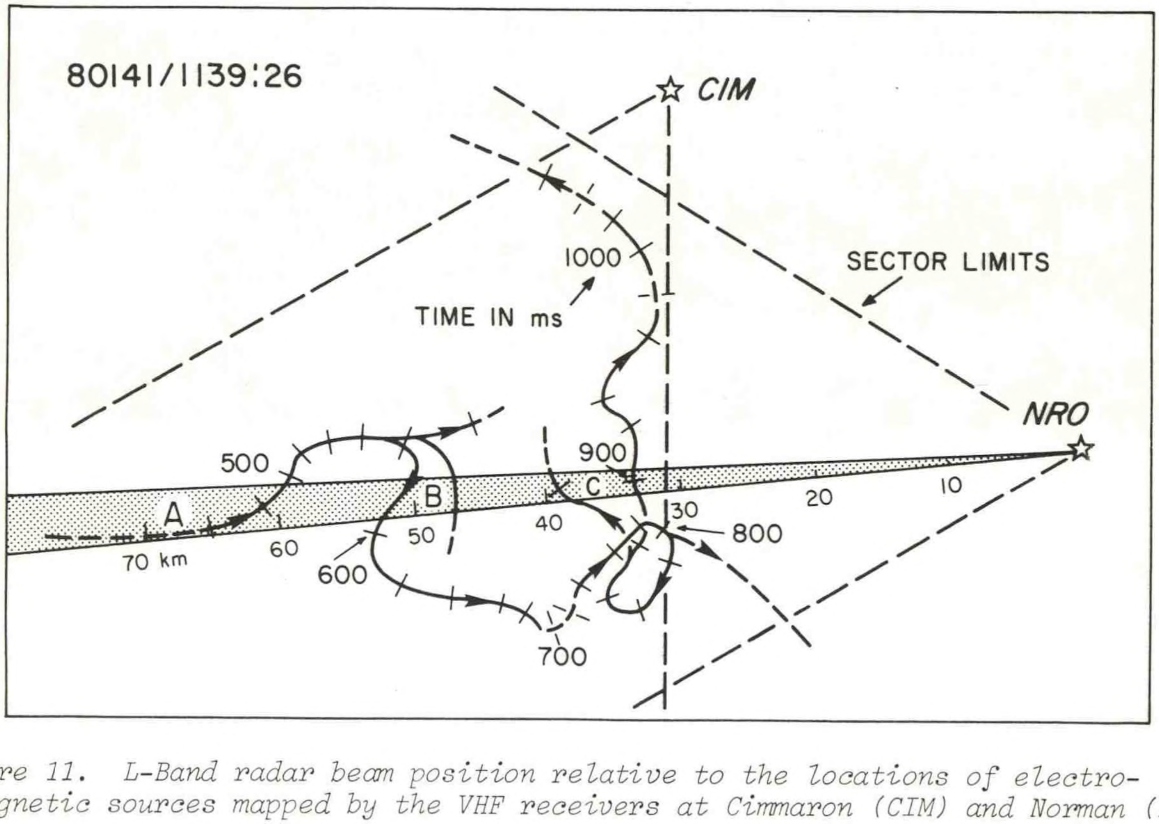

Figure 11. L-Band radar beam position relative to the locations of electromagnetic sources mapped by the VHF receivers at Cimmaron (CIM) and Norman (NRO).

because of its meandering characteristic. In the above example, progression speeds deduced from the VHF mapping data varied between 1.5 - 2.1x10^5 m s^{-1} whereas the L-band radar estimate was 0.6 - 1.1x10^5 m s^{-1}.

A four-station crossed loop direction finding network was installed to locate cloud-to-ground (CG) strike points within about 400 km of NSSL. Two of these stations were also operated as prototypes for locating lightning carrying positive charge to ground (+CG). Fig. 12 shows the progression of lightning ground strike points over a 3-hour period.

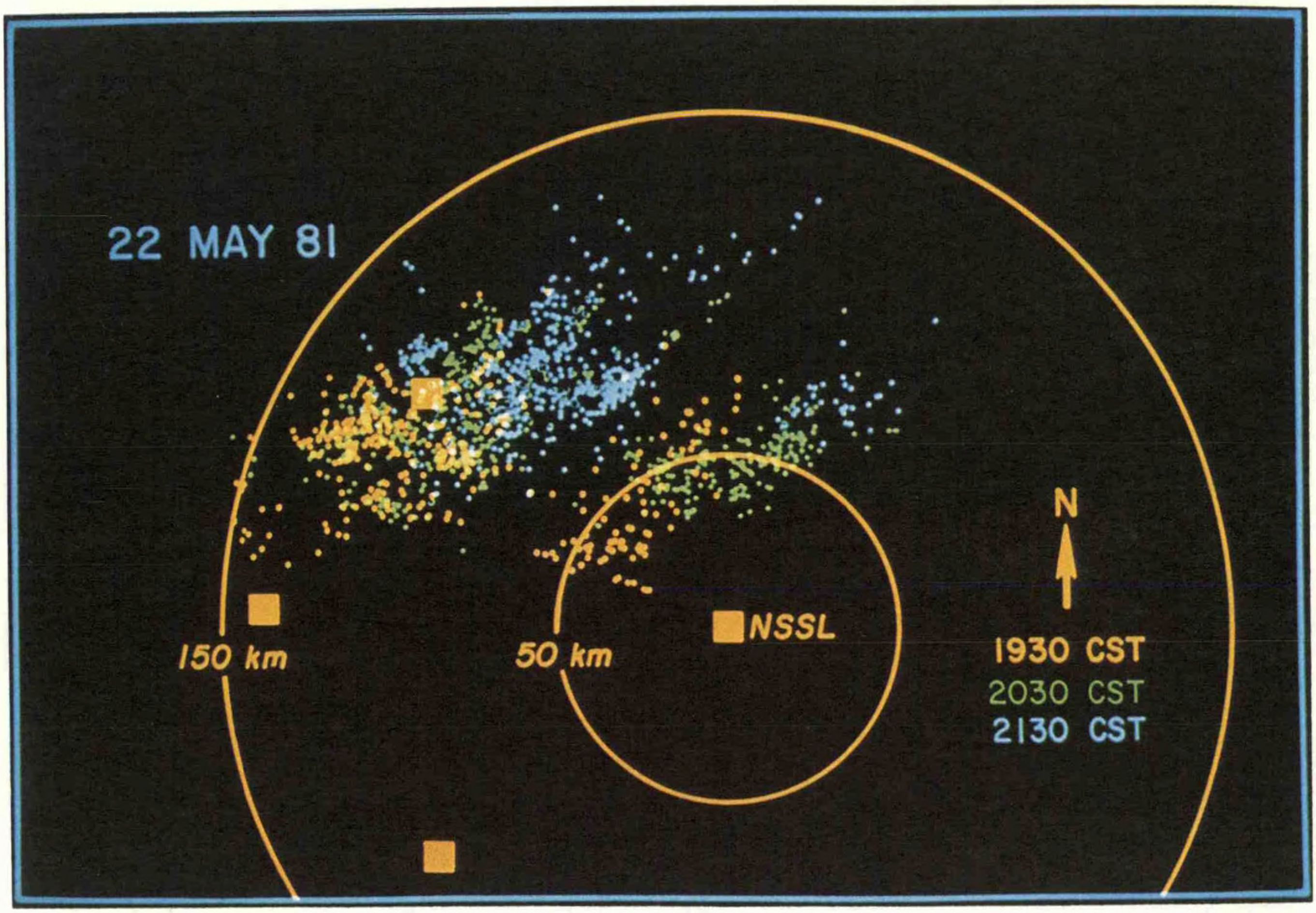

Figure 12. Tracking storms by mapping lightning ground strike locations. The four yellow squares are the stations of the ground strike locating system. Each lightning strike point is plotted as a dot, color-coded to indicate in which 30-minute period it occurred. Three alternate 30-minute periods are depicted; the listed times give the start of each period.

Positive CG flashes were verified to emanate from high on the main storm tower, through the wall cloud, and from the downshear anvil (Rust and McGorman, 1980; Rust et al. 1981). A typical field change for +CG flashes shows a slow change prior to the abrupt return stroke that is followed by a larger, slow change indicative of continuing current. Acoustic mapping of thunder sources shows that major channels of +CG flashes may extend to a height of 15 km.

The 'core' of lightning activity moves relative to the precipitation core during storm evolution. The horizontal extent of flashes increases as a storm begins to decay. Lightning was observed to propagate between individual cells in squall lines. A class of intracloud lightning has been identified that occurs almost continually at altitudes greater than 10 km in some storms. Preliminary analysis indicates high altitude flashes carry relatively small currents and have no apparent time correlation with lower altitude lightning flashes in the same storm.

EXPECTATIONS FOR FY-82

Analyses of storm electricity data obtained from all storms on 19 June 1980 will be completed. The analyses of data for 1981 and for other selected observation periods from other operations will begin. Our primary effort is to determine relationships between storm electricity and the 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 expect to obtain and analyze ELF (extremely low frequency) waveform data to test the feasibility of utilizing a hybrid ELF-optical system for detecting lightning from satellites (Vaughn et al. 1981).

During the 1982 spring field experiments, we will be acquiring the necessary data base to meet the long-term objectives.

The logic circuitry in the VHF lightning mapping system will be redesigned so that observations can be made simultaneously in all directions at impulse rates to 64,000 per second to better resolve lightning flash characteristics. The present system resolves 16,000 impulses per second in an azimuthal window 60° wide.

We expect to 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 will be developing software for analyzing data from the lightning ground strike locating system, and we will be participating in the National Interagency Coordinating Group for Atmospheric Electricity Hazards Protection for Aircraft.

ENGINEERING SUPPORT AND DEVELOPMENT GROUP

Dale Sirmans, Group Leader

INTRODUCTION

This group provides engineering development, maintenance, and operation support for the NSSL. The Group develops techniques and equipment for evolving Laboratory programs while maintaining existing systems and assisting in data acquisition and data quality control monitoring. The Group also supports the JSPO/Interim Operational Test Facility of NWS which is being activated at NSSL.

Major research facilities at NSSL include two 10-cm Doppler weather radars, a WSR-57 surveillance radar, an ATCBI-3 Beacon radar, a meteorologically instrumented 1500' tower (KTVY) and a surface observation network (52 stations).

RECENT ACCOMPLISHMENTS

Much of the NSSL engineering effort centers around support of the Spring Observational Program. In 1981, this program was oriented toward support of the atmospheric electricity observations. A limited aircraft program, special studies such as clear air observation and meteorological studies for other in-house research, and the NEXRAD program were also supported. Participation by organizations outside NSSL was not as great in 1981 as in 1980, but the in-house effort remained substantial.

Engineering development projects in direct support of the atmospheric electricity research consisted of design and development of a minicomputer data acquisition and analysis terminal and a custom data processor and recorder interface for the L-Band radar. The L-Band radar processor provides computer-compatible data suitable for semi-automated detection of lightning discharge channels.

A significant step in the upgrading of NSSL facilities for air traffic control was the replacement of the MPX-7 Interrogator with the ATCBI-3 Beacon radar. Although not the latest equipment of this type, this system represents substantial improvement of air traffic control capabilities at NSSL. We are adding a decoder and associated signal handling capability. Engineering development of the air traffic controller's display terminal continues.

The previous year's study of radar ground clutter characteristics and suppression techniques culminated in a functional design of a clutter suppression device operating on the signal envelope and thus applicable to both coherent (Doppler) and incoherent (WSR-57-type) radars. Hardware for this device will be designed and fabricated in the Equipment Development Laboratory of the National Weather Service, and tested at NSSL.

During FY-81, NSSL constructed and installed antenna elevation controllers on the NWS radars at Limon, Colorado and Cheyenne, Wyoming, in support of the ERL PROFS program. These controllers are of design similar to that used on the NSSL WSR-57 and provide limited automation of the radars for systematic data acquisition.

A request for bids was issued and a contract let for the entire solar power system to be used with NSSL's digital mesonetwork. The solar power system will decouple the NSSL mesonetwork from commercial power or rotating battery requirements and facilitate site selection and deployment of these sensors.

A proposal for NSSL to provide specific engineering development in support of the NEXRAD (next-generation radar program) was submitted to and accepted by the NEXRAD Joint System Program Office. This proposal identified two tasks, engineering development of a dual-frequency meteorological radar with emission contained within one radar emission bandwidth as defined by the FCC, and design and construction of a hardwired ground clutter suppression device specifically for the velocity channel of meteorological Doppler radars. NSSL is doing this work under contract to JSPO.

The first phase of a significant upgrading of the Radar Analysis and Display Terminal with NSSL's Doppler radar at Norman (NRO) was completed with the delivery of the Perkin Elmer 3242 computer. This system is temporarily installed in the CDP area and is being used as a stand-alone terminal pending completion of renovation of the NRO Operation Building and facilities cabling work.

The NSSL NRO Doppler Radar served as the standard for ground-based testing of airborne Doppler radars developed by Bendix and Collins for the commercial carriers. Results of the ground tests are encouraging and plans are being made for continued airborne testing next spring using the FAA DC9 training aircraft and the NSSL radar facilities.

EXPECTATIONS FOR FY-82

Engineering development and support in FY-82 will be in the general areas of support of the Spring Data Acquisition Program, equipment and techniques development for special studies and general facilities upgrading, and contract work for groups outside the NSSL.

Preliminary planning for the Spring Data Acquisition Program is for a configuration again strongly supporting atmospheric electricity observations with outside agency participation. As before, we expect an aircraft program in the new year, to include storm penetration aircraft, electric field measurements, clear air or boundary layer measurements, and evaluation of the prototype airborne Doppler radars. There are also plans for data acquisition in support of NEXRAD in both contract engineering evaluation and meteorological analysis development.

Two engineering projects are currently underway as part of preparation for the FY-82 observation program. A radar data terminal for the NSSL air traffic controller is under development as part of the ATC Facilities upgrading. This is a high resolution color display capable of mosaicing the IFF Transponder data and the WSR-57 weather data with the two radars operating independently. The minimal system is scheduled to be commissioned by April 1982 for use during the Spring Program. The Solar Power Systems for the NSSL mesonetwork are scheduled for deployment and use during the 1982 Spring Program, subject to delivery under contract terms and acceptance by NSSL.

A major engineering development effort during early FY-82 will be work under the JSPO contract noted above. We expect to complete design studies and fabrication of a closely spaced dual-frequency radar. The design is directed toward improved suppression of ground clutter over the batch method, and data acquisition rate increased about 20% with only minimal increase in frequency congestion of the meteorological radar band. NSSL's Doppler radar at Norman (NRO) will serve as the testbed for this activity and at the completion of preliminary engineering work in late winter, a decision will be made as to the configuration of the NRO radar for the spring program. If it is determined that the dual-frequency system can meet our meteorological research requirements, the radar will be operated in the dual-frequency mode during the spring. In any event, evaluation of the operational utility of dual frequency is scheduled for Spring and Summer of 1982, assuming engineering acceptance. The second task previously noted under the JSPO contract is the design and fabrication of a clutter suppression device. The NSSL real-time device will allow comprehensive testing of the hardware implementation of clutter suppression algorithms, as well as evaluation of the operational clutter problem. Engineering is scheduled for completion in January, and testing and evaluation is scheduled in Spring and Summer of 1982.

Testing and evaluation of the clutter suppression device under development by EDL/SDO/NWS noted above under FY-81 accomplishments is also scheduled in the Spring and Summer of 1982.

Installation of the P-E 3240 computer in the NRO Doppler Radar Operation Facility and completion of the radar interface is scheduled for early winter. This system and its associated peripherals will significantly increase the online computational power of the NRO Terminal and allow real-time testing of meteorological analysis techniques for the NEXRAD. Such testing will probably be conducted by the JSPO Interim Operational Test Facility located at the NSSL. An operational period is scheduled for September 1982.

COMPUTER AND DATA PROCESSING GROUP

Bill Bumgarner, Group Leader

INTRODUCTION

This group operated NSSL's principal computer systems; developed application software for engineering and meteorological support; performed quality control of data, archived data, disseminated data to outside groups; and maintained systems software for in-house computers. CDP consulted with all NSSL groups for selection of data acquisition and real-time processing equipment, evaluation of computer requirements, and recommendations for replacement hardware.

RECENT ACCOMPLISHMENTS

In support of the 1981 spring data collection program, quality control and indexing were performed for this data set-Norman and Cimarron Doppler tapes, 564; WSR-57 radar tapes, 4; and instrumented tower tapes, 51. In addition, three rawinsonde stations took 112 soundings and NSSL operated 14 stations as a surface network.

Work on the universal exchange format for Doppler data has progressed substantially. Universal format NCAR Doppler tapes were successfully converted to NSSL archive format and analyzed. NSSL produced a Cimarron Doppler tape in the universal format which was read by the NCAR FOF group. In the future, NSSL will do all exchange and internal archiving in the exchange format.

The universal format for surface data has been implemented on NSSL computers. NSSL's MR Group is converting data of important storm cases and from NCAR's PAM system to this format for internal use. The archival of the 1979 SAM data is in the final phase and will be archived in the universal format.

Work on the ERL FY-82 computer initiative continued with attendance at ERL meetings and added responses to several drafts of the RFP.

Work was finalized on specifications of a joint CIMMS-NSSL computer system and approval was given by DOC and ERL. However, because of funding considerations this plan was abandoned. In anticipation of this plan, the NCAR graphics package was installed on the University of Oklahoma's VAX computer and currently is being used by the O.U. Meteorology Department.

Instead of purchasing a VAX computer, NSSL is relying now on the P-E 3240 computer to be used principally for online radar data processing, and on telephonic connections to the CDC 750 computer at ERL Headquarters in Boulder, Colorado. The latter now represents NSSL's mainline computer capability, since the SEL 8600 was disconnected on October 1, 1981, after more than nine years service.

DATA DISSEMINATION

Data collected at the National Severe Storms Laboratory is used by many university programs, other Government agencies, and private industry. Those receiving NSSL data during the past year include:

Control Data Corp., P.O. Box O, Minneapolis, Minnesota (Richard A. Perry)
Equipment Development Laboratory, Silver Spring, Maryland (Jose Solis and Ken Shreeve)
Environmental Research Technology, Inc., Lexington, Massachusetts (Robert Crane)
Finnish Meteorology Institute, Helsinki, Finland (Robin King)
MIT - Lincoln Laboratory, Lexington, Massachusetts (John Brasunas)
NASA, Troposphere Branch, Goddard Space Flight Center, Greenbelt, Maryland (Gerald Heymsfield and Ray Wexler)
NCAR, Field Observation Facilities, Boulder, Colorado (Dick Oye)
NCAR, Convective Storms Division, Boulder, Colorado (Mark Hjelmfelt, Dennis Musil and Andrew Heymsfield)
NCAR, Mesoscale Research Section, Boulder, Colorado (Morris L. Weisman)
NCAR, Field Observation Facilities, Boulder, Colorado (Jim Wilson)
Ohio State University, Atmospheric Sciences Project, Columbus, Ohio (Thomas A. Seliga)
Oklahoma Corporation Commission, Oklahoma City, Oklahoma (Jim Winters)
Old Dominion University, Dept. of Geophysical Sciences, Norfolk, Virginia (Glen D. Coats)
Sperry, Great Neck, New York (Bill Heiss)
Sperry Gyroscope, Independence, Missouri (Les Lemon)
Texas A & M University, Department of Meteorology, College Station, Texas (Dennis P. Regan)
University of California, Department of Atmospheric Sciences, Los Angeles, California (Kerry Emanuel)
University of Oklahoma, Norman, Oklahoma (Sasaki and Dongsoo Kim)
University of Virginia, Charlottesville, Virginia (George Emmitt)
University of Washington, Seattle, Washington (Bradley F. Smull)
University of Western Ontario, London Ontario, Canada (M.J. Mikitiuk)
University of Wisconsin-Milwaukee, Milwaukee, Wisconsin (Robert Balentine)
University of Wisconsin, Madison, Wisconsin (Raymond Lord and Ronald Grosh)

EXPECTATIONS FOR FY-82

The award for the FY-82 computer initiative should be made this year with installation early in FY-83. The vitality of NSSL's research program is dependent on acquisition of a new computer and proper support.

Much effort during FY-82 will be devoted throughout the laboratory to conversion of existing programs for use on the CDC 750 at Boulder. Terminals have been installed throughout NSSL to facilitate access to the Boulder facility by NSSL scientists.

The Computer and Data Processing Group was abolished November 28, 1981, and most of its functions were transferred to the Engineering Support and Development Group. A reduction in force was involved, with loss of two positions. Mr. Bumgarner will continue to be NSSL's principal systems analyst and contact for computer-related matters having impact across the whole laboratory, and he will be our principal consultant to NSSL scientists having special computer-related problems.

COOPERATIVE INSTITUTE FOR MESOSCALE METEOROLOGICAL STUDIES (CIMMS)

Edwin Kessler

The Cooperative Institute for Mesoscale Meteorological Studies is a joint venture of the University of Oklahoma and NOAA/ERL through the National Severe Storms Laboratory. CIMMS is modeled after other NOAA joint institutes on university campuses. The program objectives and activities of CIMMS should complement and supplement those at NSSL and the University through research conducted by Visiting Fellows, NOAA and University staff, and student appointees.

During its first two years CIMMS was led by Interim Director Rex L. Inman, also 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. The Council of Fellows which consults with the Director concerning ongoing matters of policy, numbers four at present: Drs. Peter S. Ray and Dusan S. Zrnic' of NSSL, both of whom hold adjunct appointments at O.U., and Profs. R. Inman and Y. Sasaki of O.U. In addition, Dr. John McCarthy, formerly a professor at O.U. and now at the National Center for Atmospheric Research, is an Associate Fellow. The Advisory Council meets annually and includes several officials of NOAA, officers of the University of Oklahoma, and representatives of other government agencies and the academic community.

During FY-79, CIMMS hosted six visiting scientists from periods of a few days to a few months. Longest in residence was Dr. Kerry Emanuel of UCLA, whose comprehensive analyses of inertial motions and mesoscale convection were printed in the Journal of Atmospheric Sciences.

During FY-80, CIMMS produced two significant reports, the first a collection of lecture notes, "Dynamics of Mesometeorological Disturbances," which are proceedings of a symposium on that subject held from May 12th to 16th, 1980, and attended by approximately 70 meteorologists from around the United States. The second is a comprehensive review "Laboratory Tornado Vortices" by CIMMS Visiting Scientist N. Monji from Japan.

During 1981, four significant reports were published and others works are in press in the peer-reviewed literature. Topics include structure of the planetary boundary layer, retrieval of transverse winds from single-Doppler radar data, variational analysis, and a nonhydrostatic axisymmetric hurricane model with prospects for adaptation to the three-dimensional mesoscale. During April-July 1981, CIMMS sponsored a series of nine special lectures presented by leading meteorologists from various places in the United States. During FY-81 there were 13 students employed in CIMMS, and there were 10 postdoctoral fellows and research associates from the United States, Japan, Taiwan, Republic of China, and Finland.

CIMMS' base funding provided through NSSL continues at the starting level of $100,000 per year, and additional funds through NSSL to support employment of students amounted to about $150,000 during FY-81. Salaries of some Fellows from foreign countries are supported wholly or in part by their governments; these persons bring fresh viewpoints, active minds, and
while impacting the CIMMS budget only slightly.

Its financial base is small, but CIMMS has attracted some additional funds from NASA. This is a bright sign, especially in view of funding cutbacks in government. Two of several promising postdoctoral researchers have received appointments to CIMMS tenable during FY-82, and it seems certain that CIMMS will continue to be characterized by a staff of high quality.

A meeting of the CIMMS Advisory Board was convened on September 21, 1981. An important topic was the projected new Energy Center at The University of Oklahoma, to be endowed with both private and State funds. It has been proposed that this include a Weather Center inhabited by the O.U. Department of Meteorology, the Oklahoma Climate Survey, CIMMS, and the research side of NSSL. Sharing of certain basic facilities could represent significant savings to the participating organizations, and opportunities for improved flow of ideas. Since CIMMS and the Meteorology Department are inadequately housed at present, the Energy Center also offers the enticement of markedly improved office and research space for those organizations.

ADMINISTRATIVE GROUP

Loyce Tillman, Administrative Officer

PERSONNEL

At the end of FY-81 the NSSL had a staff of 42 full-time, three part-time, one Junior Fellow and 18 intermittent employees.

Our personnel staff continues to be supplemented by contracts with the University of Oklahoma and applied Computer Systems.

LAND AND BUILDINGS

Leases on land and buildings utilized by NSSL during FY-81 were substantially unchanged from FY-80.

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 sq. ft. of usable space.
b) Ground space of 718 sq. ft. for a rawinsonde facility.
c) Ground space of 17,280 sq. ft. 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 sq. ft. 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 antennae;
   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 sq. ft. used for placement of sensors to measure various parameters of storm electricity. Located on ground space is an 800 sq. ft. 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 $8,000 annually.

Additional leased space includes:

h) 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.
i) Leased space at Chickasha, Oklahoma containing a rawinsonde site and mesonetwork equipment.
j) 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.
k) 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.
l) Land agreements for 52 network sites.

Total annual cost for all items h through l above is approximately $27,758.00.

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.

GRANTS AND CONTRACTS

Grants and contracts administered by NSSL during FY-81 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
	GRANTS			
Florida State University "Analysis of Small Cumulus Fields during SESAME Thermal Convection Experiments" (Mach)	NA81RAD00004 ($7,882.00)	Ray	10/1/80	12/9/81
University of Oklahoma "Radar Studies of Lightning in Thunderstorms" (Walker)	NA80RAD00002 ($13,982.00)	Rust	10/1/79	3/31/82
University of Mississippi "Storm Electricity in Severe Convective Storms" (Arnold)	NA79RAD00007 ($40,017.00) (NASA funds)	Rust	1/7/81	3/31/82
Miami University "A Field Investigation of Electric Currents Associated with Severe Local Storms" (Church)	NA81RAA00259 ($6,536.00)	Rust	4/1/81	12/31/81
University of Purdue "Research on Severe Local Storms" (Agee)	NA80RAD00026 ($7,000.00)	Ray	9/1/81	9/30/82
University of Washington "Studies of Severe Convective Storms" (Houze)	NA80RAD00025 ($9,849.00)	Ray	9/14/81	9/30/82

CONTRACTS

Applied Computer Systems "Services for Facilities Management to operate NSSL Computer Equipment"	NA81RAE00036 ($77,000.00)	Bumgarner	12/10/80	9/30/81
Systems Engineering Laboratories "Lease and Maintenance of Computer"	NA80RAE00032 ($73,428.00)	Bumgarner	10/1/80	9/30/81
Scott AFB "6th Weather Squadron (Mobile) (MAC) support to NSSL Spring Program"	NA81RAG01628 ($8,396.24)	Lee	4/1/81	6/30/81
Environmental Research & Technology, Inc. "Radar Analyses for Severe Weather Detection Tracking and Prediction and Depiction"	NA81RAC00072 ($124,251.00) (FAA funds)	Lee	4/1/81	6/30/82
University of Oklahoma "Cooperative Institute for Mesoscale Meteorological Studies"	NA80RAH00004 ($88,461.00)	Kessler	10/1/80	9/30/81

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October 1, 1980 - September 30, 1981

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AS OF SEPTEMBER 30, 1981

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 $3.50 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)

No. 7 The vertical structure of Three Dry Lines as Revealed by Aircraft Traverses. E. L. McGuire. April 1962. 10 p. (PB-168213)

No. 8 Radar Observations of a Tornado Thunderstorm in Vertical Section. Ralph J. Donaldson, Jr. April 1962. 21 p. (PB-174859)

No. 9 Dynamics of Severe Convective Storms. Chester W. Newton. July 1962. 44 p. (PB-163319)

No. 10 Some Measured Characteristics of Severe Storms Turbulence. Roy Steiner and Richard H. Rhyne. July 1962. 17 p. (N62-16401)

No. 11 A Study of the Kinematic Properties of Certain Small-Scale Systems. D. T. Williams. October 1962. 22 p. (PB-168216)

No. 12 Analysis of the Severe Weather Factor in Automatic Control of Air Route Traffic. W. Boynton Beckwith. December 1962. 67 p. (PB-168217)

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)

No. 15 Penetrations of Thunderstorms by an Aircraft Flying at Supersonic Speeds. G. P. Roys. Radar Photographs and Gust Loads in Three Storms of 1961 Rough Rider. Paul W. J. Schumacher. May 1963. 19 p. (PB-168220)

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No. 18 The Thunderstorm Wake of May 4, 1961. D. T. Williams. August 1963. 23 p. (PB-168223)

No. 19 Measurements by Aircraft of Condensed Water in Great Plains Thunderstorms. George P. Roys and Edwin Kessler. July 1966. 17 p. (PB-173048)

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)

No. 21 On the Motion and Predictability of Convective Systems as Related to the Upper Winds in a Case of Small Turning of Wind with Height. James C. Fankhauser. January 1964. 36 p. (PB-168225)

No. 22 Movement and Development Patterns of Convective Storms and Forecasting the Probability of Storm Passage at a Given Location. Chester W. Newton and James C. Fankhauser. January 1964. 53 p. (PB-168226)

No. 23 Purposes and Programs of the National Severe Storms Laboratory, Norman, Oklahoma. Edwin Kessler. December 1964. 17 p. (PB-166675)

No. 24 Papers on Weather Radar, Atmospheric Turbulence, Sferics and Data Processing. August 1965. 139 p. (AD-621586)

No. 25 A Comparison of Kinematically Computed Precipitation with Observed Convective Rainfall. James C. Fankhauser. September 1965. 28 p. (PB-168445)

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)

No. 28 Movement and Predictability of Radar Echoes. James Warren Wilson. November 1966. 30 p. (PB-173972)

No. 29 Notes on Thunderstorm Motions, Heights, and Circulations. T. W. Harrold, W. T. Roach, and Kenneth E. Wilk. November 1966. 51 p. (AD-644899)

No. 30 Turbulence in Clear Air Near Thunderstorms. Anne Burns, Terence W. Harrold, Jack Burnham, and Clifford S. Spavins. December 1966. 20 p. (PB-173992)

No. 31 Study of a Left-Moving Thunderstorm of 23 April 1964. George R. Hammond. April 1967. 75 p. (PB-174681)

No. 32 Thunderstorm Circulations and Turbulence from Aircraft and Radar Data. James C. Fankhauser and J. T. Lee. April 1967. 32 p. (PB-174860)

No. 33 On the Continuity of Water Substance. Edwin Kessler. April 1967. 125 p. (PB-175840)

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

No. 35 A Theory for the Determination of Wind and Precipitation Velocities with Doppler Radars. Larry Armijo. August 1967. 20 p. (PB-176376)

No. 36 A Preliminary Evaluation of the F-100 Rough Rider Turbulence Measurement System. U. O. Lappe. October 1967. 25 p. (PB-177037)

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)

No. 39 Thunderstorm - Environment Interactions Revealed by Chaff Trajectories in the Mid-Troposphere. James C. Fankhauser. June 1968. 14 p. (PB-179659)

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No. 41 Structure and Movement of the Severe Thunderstorms of 3 April 1964 as Revealed from Radar and Surface Mesonetwork Data Analysis. Jess Charba and Yoshikazu Sasaki. October 1968. 47 p. (PB-183310)

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

No. 43 Detection and Presentation of Severe Thunderstorms by Airborne and Ground-based Radars: A Comprehensive Study. Kenneth E. Wilk, John K. Carter, and J. T. Dooley. February 1969. 56 p. (PB-183572)

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

No. 45 On the Relationship Between Horizontal Moisture Convergence and Convective Cloud Formation. Horace R. Hudson. March 1970. 29 p. (PB-191720)

No. 46 Severe Thunderstorm Radar Echo Motion and Related Weather Events Hazardous to Aviation Operations. Peter A. Barclay and Kenneth E. Wilk. June 1970. 63 p. (PB-192498)

No. 47 Evaluation of Roughness Lengths at the NSSL-WKY Meteorological Tower. Leslie D. Sanders and Allen H. Weber. August 1970. 24 p. (PB-194587)

No. 48 Behavior of Winds in the Lowest 1500 ft in Central Oklahoma: June 1966-May 1967. Kenneth C. Crawford and Horace R. Hudson. August 1970. 57 p. (N71-10615)

No. 49 Tornado Incidence Maps. Arnold Court. August 1970. 76 p. (COM-71-00019)

No. 50 The Meteorologically Instrumented WKY-TV Tower Facility. John K. Carter. September 1970. 18 p. (COM-71-00108)

No. 51 Papers on Operational Objective Analysis Schemes at the National Severe Storms Forecast Center. Rex L. Inman. November 1970. 91 p. (COM-71-00136)

No. 52 The Exploration of Certain Features of Tornado Dynamics Using a Laboratory Model. Neil B. Ward. November 1970. 22 p. (COM-71-00139)

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No. 55 The NSSL Surface Network and Observations of Hazardous Wind Gusts. Operations Staff. June 1971. 20 p. (COM-71-00910)

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No. 58 The Thermal Structure of the Lowest Half Kilometer in Central Oklahoma: December 9, 1966-May 31, 1967. R. Craig Goff and Horace R. Hudson. July 1972. 53 p. (COM-72-11281)

No. 59 Cloud-to-Ground Lightning Versus Radar Reflectivity in Oklahoma Thunderstorms. Gilbert D. Kinzer. September 1972. 24 p. (COM-73-10050)

No. 60 Simulated Real Time Displays of Velocity Fields by Doppler Radar. L. D. Hennington and G. B. Walker. November 1972. 10 p. (COM-73-10515)

No. 61 Gravity Current Model Applied to Analysis of Squall-Line Gust Front. Jess Charba. November 1972. 58 p. (COM-73-10410)

No. 62 Mesoscale Objective Map Analysis Using Weighted Time-Series Observations. Stanley L. Barnes. March 1973. 60 p. (COM-73-10781)

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