NOAA Technical Memorandum ERL NSSL-96

1983 SPRING PROGRAM SUMMARY

J. T. Dooley, Editor

Contributors:

Robert P. Davies-Jones
Sherman Fredrickson
Carl Hane
Jean T. Lee
Donald R. MacGorman
Robert M. Rabin
Peter S. Ray
W. David Rust
Lester C. Showell
Dale Sirmans
Roland Stull
William L. Taylor

Property of
NWC Library
University of Oklahoma

National Severe Storms Laboratory
Norman, Oklahoma
April 1984

UNITED STATES DEPARTMENT OF COMMERCE

Malcolm Baldrige, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

John V. Byrne, Administrator

Environmental Research Laboratories

Vernon E. Derr Director

NOTICE

Mention of a commercial company or product does not constitute an endorsement by NOAA Environmental Research Laboratories. Use for publicity or advertising purposes of information from this publication concerning proprietary products or the tests of such products is not authorized.

Table of Contents

		PAGE
1.	INTRODUCTION	1
2.	EXPERIMENTS: PRINCIPAL INVESTIGATORS AND OBJECTIVES	2
2.1	Tornadic Storm	2
2.2	Storm Evolution	2
2.3	Ground Truth for NASA U-2 Lightning Study	2
2.4	Lightning and Storm Structure	2
2.5	Measurements of Electric Field Inside Severe Storms	3
2.6	Electric Field from Coronasondes and Acoustic Mapping of Lightning	3
2.7	Corona Beneath Severe Storms	3
2.8	Simultaneous Extremely Low Frequency (ELF) Observations at NSSL and NASA/MSFC	3
2.9	Storm Electricity Experiments Using Mobile Laboratory	3
2.10	Gust Gradients and Turbulence Measurements	4
2.11	Storm Formation at Outflow Boundaries	4
2.12	Gust Front Evolution	4
2.13	Tornado Intercept	5
2.14	Aspect Sensitivity of Doppler Spectrum Width	5
2.15	Prestorm and Areas of Deep Convection	5
2.16	University of Wisconsin Boundary Layer Experiment	5
2.17	Relationship Between Radar Reflectivity in Clear Air and Integrated Water Vapor	6
2.18	Precipitation Spectra with Doppler Radar Using Lightning Channels as Wind Tracers	6
3.	INSTRUMENTATION	7
3.1	Doppler Radars	8
3.2	WSR-57	8
3.3	Automated Mesonetworks	8
3.4	NSSL-KTVY Meteorological Tower Facility	9
3.5	Rawinsonde	9
3.6	Very High Frequency (VHF) Lightning Mapping System	9
3.7	Storm Electricity Building (SEB)	10
3.8	Lightning Strike Locator	10
3.9	Photo Documentation	10
3.10	Storm Electricity Measurements from Balloons	10
3.11	Storm Electricity Mobile Laboratory	11
3.12	NSSL Mobile Laboratories (NSSL-OU)	11
3.13	NASA B-57B	11
3.14	NASA U-2	11
3.15	NOAA RFC WP-3D	12

PAGE

4. OPERATIONAL PERIODS, DAILY WEATHER SUMMARIES, AND NOTES ON OBSERVATIONS 13

4.1 16 May - Julian day 136 14
4.2 17 May - Julian day 137 15
4.3 18 May - Julian day 138 17
4.4 19 May - Julian day 139 18
4.5 20 May - Julian day 140 19
4.6 21 May - Julian day 141 21
4.7 22 May - Julian day 142 22
4.8 23 May - Julian day 143 23
4.9 24 May - Julian day 144 24
4.10 25 May - Julian day 145 25
4.11 26 May - Julian day 146 27
4.12 27 May - Julian day 147 28
4.13 28 May - Julian day 148 30
4.14 29 May - Julian day 149 31
4.15 30 May - Julian day 150 32
4.16 31 May - Julian day 151 33
4.17 1 June - Julian day 152 34
4.18 2 June - Julian day 153 35
4.19 3 June - Julian day 154 36
4.20 4 June - Julian day 155 37
4.21 5 June - Julian day 156 38
4.22 6 June - Julian day 157 40
4.23 7 June - Julian day 158 41
4.24 8 June - Julian day 159 42
4.25 9 June - Julian day 160 43
4.26 10 June - Julian day 161 44

ACKNOWLEDGMENTS 46

APPENDICES

APPENDIX A The University of Wisconsin 1983 Boundary Layer Experiment 47

APPENDIX B NSSL Doppler Radars 48

APPENDIX C NSSL Stationary Automated Mesonetwork (SAM) 52

1983 Spring Program Summary

1. INTRODUCTION

The National Severe Storms Laboratory (NSSL) is involved both with the collection of data and its analysis. This report describes the major data acquisition effort during 1983, and its scientific objectives. Researchers interested in data sets for analysis may contact J T Dooley, Data Dissemination Coordinator at NSSL, or the principal investigator of the experiment of interest.

The 1983 Spring Program of the NSSL differed from previous programs in its support of operational tests of the Next Generation Radar (NEXRAD). This support was extended for 6 weeks beginning on April 4. For 4-weeks beginning May 16, NSSL scientists and other investigators sought to collect data to meet needs of particular experiments. On June 13, support again was shifted to NEXRAD. This report encompasses the research period, May 16 through June 10.

Principal objectives of the 1983 observation program were to (1) acquire a dual Doppler data set from a tornadic and/or supercell status storm, (2) increase the data base of the Storm Electricity Group with emphasis on ground truth of lightning characteristics for comparison with airborne measurements to aid development of a satellite sensor for lightning detection, (3) support other groups in experiments related to the electric field inside and around thunderstorms, (4) measure the structure of wind and reflectivity in clear air, (5) measure gust gradients in adverse meteorological conditions with special emphasis on airport approach and departure flight paths, (6) obtain tornado proximity data with the Totable Tornado Observatory (TOTO) and (7) support other agencies in measurement of parameters related to the boundary layer.

As in the past, the 1983 base program was principally an in-house effort: however, other groups participated, thus enhancing the data sets that were collected: (1) The University of Oklahoma, as part of NSSL's Tornado Intercept Project, conducted an experiment to place an instrumented package (TOTO) near tornadoes. (2) A University of Mississippi team observed lightning activity with a mobile laboratory in conjunction with NASA's U-2 aircraft; in addition it manned a fixed-based observatory for launch of balloon-borne sensors to measure the vertical profile of the electric field in storm environs. (3) A Rice University team set up three rawinsonde units at Chickasha and flew modified instrument packages to determine the gross charge distribution in storms. (4) NASA's B-57B aircraft collected data on turbulence and gusts in the vicinity of large organized storms. (5) NOAA's WP-3D aircraft enhanced NSSL's ground-based Doppler radar capabilities by collecting data on two occasions in the vicinity of severe storms.

Although the 1983 season provided below-average severe thunderstorm activity in central Oklahoma, scientists collected a substantial amount of data.

2. EXPERIMENTS: PRINCIPAL INVESTIGATORS AND OBJECTIVES

2.1 Tornadic Storm (Brandes)

Objective:

To acquire a dual Doppler data set from a tornadic storm well positioned within the radar network.

2.2 Storm Evolution (Brown)

Objectives:

a. Understand the complete four-dimensional evolution of thunderstorms.

b. Delineate the storm-produced mechanisms and organization that culminate in tornado occurrence.

c. Specify the distribution and characteristics of hail and strong winds.

d. Relate supercell radar parameters to storm electricity production.

2.3 Ground Truth for NASA U-2 Lightning Study (Rust, Christian, and Arnold)

Objective:

Provide measurements of lightning characteristics (optical waveform, IC/CG identification, location, number of strokes) and compare these with simultaneous airborne measurements made above storms to help develop a satellite sensor for lightning detection.

2.4 Lightning and Storm Structure (Taylor, MacGorman, and Rust)

Objectives:

a. Map lightning discharge processes and ground strike points.

b. During different periods of storm lifetime, determine relationships among coevolving fields of precipitations, wind, turbulence, and lightning (by flash type, polarity, etc.).

c. Determine lightning initiation regions, measure progression speeds for different lightning processes, and relate these to storm parameters.

d. Measure lightning parameter characteristics indicative of tornadic, severe nontornadic, and nonsevere storms.

e. Determine the occurrence and physical characteristics of positive cloud-to-ground (+CG) flashes relative to storm severity and stage of development.

f. Develop a lightning ground strike climatology by continuously recording CG strike data.

2.5 Measurements of Electric Field Inside Severe Storms (Marshall, Rust)

Objectives:

a. Determine vertical profile of electric field inside and around severe storms.

b. Estimate charge density within severe storms.

2.6 Electric Field from Coronasondes and Acoustic Mapping of Lightning (Few, MacGorman)

a. Measure the vertical electric field and other environmental parameters with modified radiosondes to provide information on the gross charge distribution in storms.

b. Locate lightning channels inside storms from recordings of thunder to correlate with in situ electric field measurements and with storm features.

2.7 Corona Beneath Severe Storms (Rust)

Objectives:

a. Measure corona current over large area beneath severe storms.

b. Determine contribution large storms make to the earth/electrosphere current system.

2.8 Simultaneous Extremely Low Frequency (ELF) Observations at NSSL and NASA/MSFC (Taylor, Christian, and Goodman)

Objectives:

a. Test feasibility of using ELF signals from lightning to detect cloud-to-ground flashes at long ranges.

b. Provide corroborative evidence for positive cloud-to-ground flashes.

2.9 Storm Electricity Experiments Using Mobile Laboratory (Arnold, Marshall, and Rust)

Objectives:

a. Correlate lightning activity with storm dynamics inferred from visual and radar measurements.

b. Document the electrical and optical characteristics of lightning measured simultaneously at the ground and from above the storms with the NASA U-2.

c. Determine surface electric fields beneath mesocyclones.

d. Document lightning flashes to ground and identify +CG flashes for comparison with Lightning Location and Protection (LLP) and ELF observations.

e. Determine +CG flash characteristics and their location relative to storm structure.

f. Estimate height and magnitude of charge lowered to ground by lightning in the vicinity of mesocyclones.

g. Determine feasibility of mobile launching of balloons for measuring electric fields inside severe storms.

2.10 Gust Gradients and Turbulence Measurements (Lee)

Objectives:

a. Measure gusts and spanwise gust gradients in adverse meteorological conditions with special emphasis on approach and departure flight paths.

b. From measurements, develop mathematical/statistical models to analyze and improve aircraft wing design and safety of landings and takeoffs.

2.11 Storm Formation at Outflow Boundaries (Zrnic')

Objectives:

a. Determine triggering mechanism of storm outflow boundaries for new storm development.

b. Document the interaction of outflow boundaries and gust fronts with the planetary boundary layer over a radius of 100 km.

2.12 Gust Front Evolution (Lee)

Objectives:

a. Determine gust front evolution and source.

b. Determine forecast parameters of downdraft and gust front formation and intensity.

2.13 Tornado Intercept (Davies-Jones)

Objectives:

a. Place TOTO in projected paths of tornadoes.

b. Obtain supporting photographic, visual, and quantitative documentation of storm for interpretation of TOTO and Doppler radar observations.

c. Obtain close-range movies of tornadic debris clouds.

d. Obtain close-in time lapse movies of mesocyclones.

2.14 Aspect Sensitivity of Doppler Spectrum Width (Zrnic')

Objective:

Determine if spectrum width due to turbulence is sensitive to the aspect angle of the radar beam, i.e., to what degree turbulence in storm is horizontally isotropic.

2.15 Prestorm and Areas of Deep Convection (Doviak, Rabin)

Objectives:

To measure the structure of wind and reflectivity in clear air or in Areas of Deeper Convection (ADC) prior to storms and to determine if the onset and intensity of the precipitation can be predicted using observations with Doppler radar. This includes the following:

a. Identification of frontal boundaries, divergence, and deformation in real time, giving the radar meteorologists and nowcaster current status on the changing environment as well as a cursory comparison between satellite photographs and other field observations.

b. Mesoscale wind mapping using both single and dual Doppler analysis.

c. Observations of ADC's and their possible evolution into convective precipitation; relating their structure and movement to the wind fields.

2.16 University of Wisconsin Boundary Layer Experiment (Doviak, Rabin, and Stull)

Objectives:

a. Obtain observations of the life history of small cumulus clouds.

b. Determine the fraction of the cloud field composed of active cloud.

c. Estimate the rate at which boundary layer air is circulated through clouds.

d. Compare lidar and aircraft-measured turbulence near cloud base.

e. Estimate the resonant interaction between thermals and features on the earth's surface.

f. Study the change in entrainment and mixing layer growth when clouds are present.

Additional details relating to the Boundary Layer Experiment are given in Appendix A.

2.17 Relationship Between Radar Reflectivity in Clear Air and Integrated Water Vapor (Zrnic')

Objectives:

a. Determine if there is a relationship between integrated water vapor as measured by a radiometer and reflectivity measured by radar.

b. Supplement the cooperative experiment with the University of Wisconsin and the prestorm experiment.

2.18 Precipitation Spectra with Doppler Radar Using Lightning Channels as Wind Tracers (Rust, Taylor, and Mazur)

Objectives:

a. Determine precipitation drop size spectra using lightning as a tracer for vertical winds.

b. Measure characteristics of Doppler spectrum of lightning, i.e., cross section per unit volume, spectrum width, and duration of signature.

c. Study lightning as a tracer for vertical wind.

3. INSTRUMENTATION

This section briefly describes the equipment and facilities (Fig. 1) employed in data acquisition during the 1983 Spring Program. Where appropriate, details of each sensing device have been included. In addition detailed specifications and/or descriptions of selected observing systems are presented in the appendices.

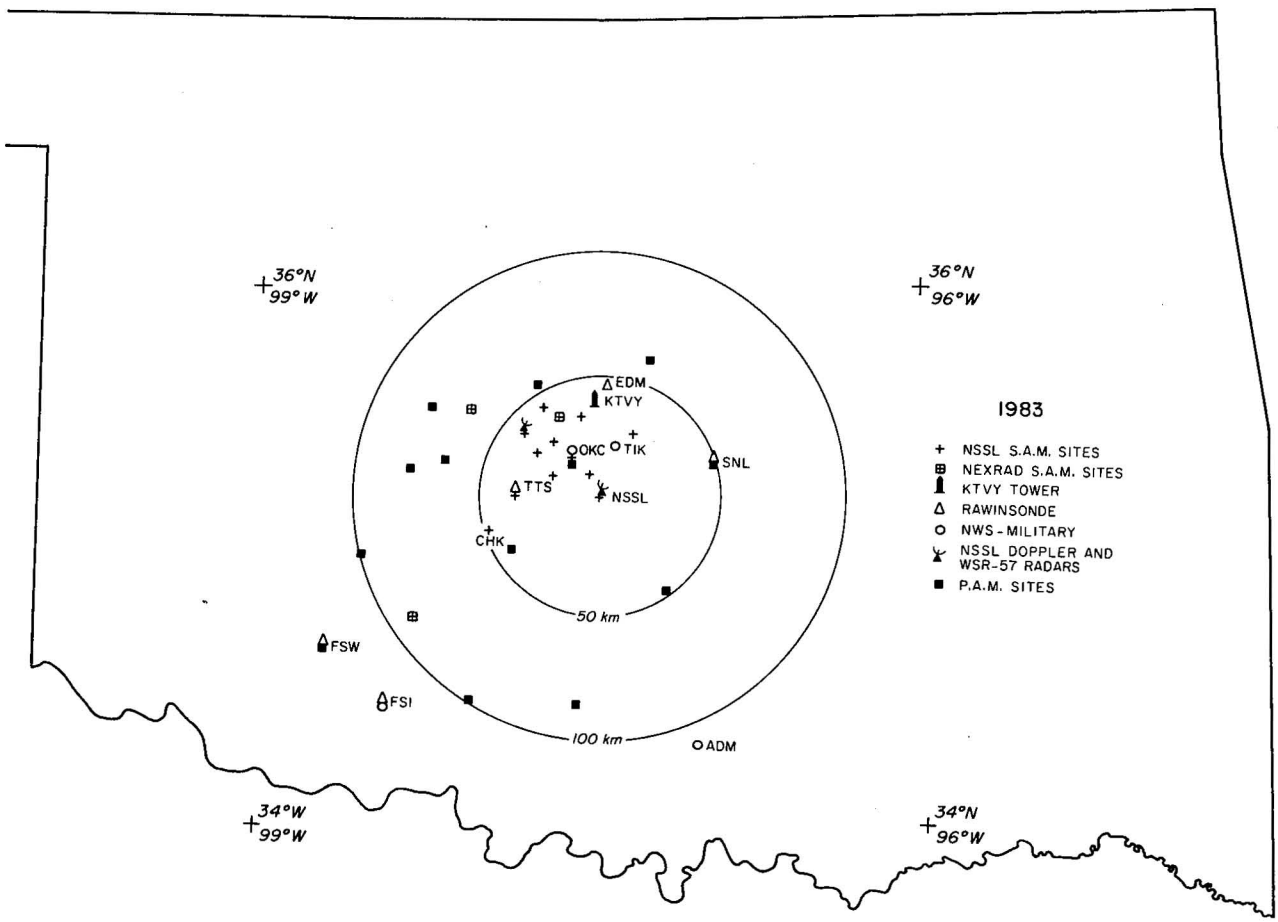


Figure 1. 1983 Facilities

3.1 DOPPLER RADARS

NSSL operates two 10-cm Doppler radar systems, one (NRO) located at NSSL and the other (CIM) at Page Field near Yukon, Oklahoma, 41 km northwest of NSSL. Each radar records either or both the three moments (power, mean velocity, and spectrum width) of the Doppler spectrum at all ranges and/or the time series samples of the Inphase (I) and Quadrature phase (Q) video signals sampled simultaneously at 16 range locations. Both systems give a choice of four pulse repetition times (PRT's) and several options in transmitting pulses: (a) a uniform train for Doppler spectral analysis, (b) an interlaced PRT (dual sampling mode) for automated range de-aliasing of multiple trip targets and monitoring of range overlaid echoes, and (c) a long transmitted pulse width (3-5 μsec) for improved sensitivity for detection of clear air echoes (See Appendix B for detailed characteristics of NSSL's Doppler radars.).

3.2 WSR-57

NSSL also operates a 10-cm incoherent surveillance radar (WSR-57) located at NSSL. This radar has angular resolution of about 2° and a range resolution of 1 km (for most experiments). It provides reflectivity estimates, scans at a rate of 12° per second in azimuth, and automatically steps in elevation at increments selected by the operator. The system is usually operated hands-off in a preset surveillance mode. Data are recorded on 35-mm film for each scan. A color representation of a full scan is recorded on a computer disk every 15 to 20 minutes. Polaroid pictures of the main console PPI are taken at 30 minute intervals. Data are available from 10 May 1983 to 13 June 1983 for most storm days.

3.3 AUTOMATED MESONETWORKS

Two independent stationary automated mesonetworks were deployed in 1983 (See Appendix C for detailed characteristics of the NSSL stationary automated mesonetwork.).

A 12-station network located northwest of NSSL was operated in support of the NSSL research period. Surface data were archived during the period 12 May 1983 to 8 June 1983.

A three-cluster network was operated in support of The NEXRAD research project. Four stations were located at Wiley Post Airport in Oklahoma City, five stations were located at Fort Reno (west of El Reno), and five stations were located at Fort Sill, Oklahoma. Each cluster provided a small-area sample of surface meteorological data; the spacing of the stations at each cluster was based on NSSL's Doppler radar's sample volume at the range of each cluster. Surface data were archived during the periods 4 April 1983 to 11 May 1983 and 10 June 1983 to 7 July 1983. A separate portable automated mesonetwork (PAM) deployed by NCAR, was operated during part of the NSSL research period in support of the University of Wisconsin Boundary Layer Experiment.

3.4 NSSL-KTVY METEOROLOGICAL TOWER FACILITY

The 461-m KTVY television antenna tower has been used as a multi-level boundary layer sensor facility since 1966. Currently, it is instrumented at seven levels: 7, 26, 45, 89, 177, 266 and 444 m. Thirty-five channels of weather data are routinely recorded on 7-track magnetic tape, partitioned into 7 horizontal wind speeds, 7 wind directions, 6 vertical wind speeds, 7 dry bulb temperatures, 4 wet bulb temperatures, 2 digital pressures, a rain gage and a pyranometer. An approximate 1-second sample interval is used during storm periods, and a 10-second sample interval is used during non-storm conditions. Data were recorded continuously from 1 April 1983 to 6 July 1983.

3.5 RAWINSONDE

The 1983 rawinsonde network was comprised of four units in central Oklahoma. Units at Edmond, Shawnee, and five miles south of Tuttle, Oklahoma, were operated by personnel from the U. S. Air Force Sixth Weather Squadron Mobile. A fourth unit located at Fort Sill's west range north of Cache, Oklahoma, was operated by the U. S. Army Field Artillery Board. The 75th Field Artillery Brigade and the 212th Brigade at Fort Sill supported daily morning and afternoon soundings to 400 mb to aid the NSSL forecasting team.

Support soundings were taken at the Shawnee site to aid the University of Wisconsin boundary layer experiment (BLEX). The Tuttle site supported the University of Mississippi with special storm electricity probes attached to the balloon train. Rice University had three rawinsonde units set up at the Chickasha airport, and NSSL rawinsonde control gave support to these operations.

3.6 VERY HIGH FREQUENCY (VHF) LIGHTNING MAPPING SYSTEM

A wide-band VHF system, employing time-difference-of arrival techniques, provided azimuth and elevation angles to individual sources of electromagnetic impulses from lightning discharges. Acceptable elevation angles were limited to 45 degrees above the horizon; azimuth angles were limited to a 120-degree sector, selectable in 60-degree increments. Angles were determined to 0.5-degree accuracy in azimuth for lightning occurring within a nominal 60-km range. Maximum instantaneous rate of reception was 16,000 per second. Data were recorded on 9-track magnetic tape, and time was synchronized to WWV. A real-time azimuth-elevation display was available to assist in detecting and tracking thunderstorms. Simultaneous observations were made at NSSL in Norman and south of Page Field at the Cimarron site. The equipment at Norman could be switched into an overhead viewing mode to observe lightning activity within a cone extending down to approximately 30 degrees above the horizon.

3.7 STORM ELECTRICITY BUILDING (SEB)

The SEB served as a central location for acquisition of storm electricity data and coordination with other areas of experimental data collection. Instrumentation located at and in the area near the SEB was used to measure various electrical phenomena such as electric field changes associated with lightning; optical transients from lightning; and visual, photographic, and video documentation of lightning and storms. Data were recorded on analog magnetic tape and strip chart with time code snychronized to WWV.

3.8 LIGHTNING STRIKE LOCATOR

The cloud-to-ground (CG) lightning location system provided the time, location, peak field strength, and number of component strokes for each CG flash within about 400 km of Norman. The system consisted of four remote direction finders (DF's) which independently determined the azimuth angle to the lower portions of CG channels. Direction finders were located at Norman (DF1), Fort Sill (DF2), Cordell (DF3), and Watonga (DF4). All four sites were modified to locate CG flashes that lower positive charge, as well as the more frequent flashes that lower negative charge. The data from the direction finders were transmitted to a position analyzer in the SEB that computed the intersection point of the azimuth angles in real time and presented data to digital magnetic tape, hard copy printer, and plotter.

3.9 PHOTO DOCUMENTATION

Two 35-mm motor-driven cameras were modified to continuously and smoothly advance black and white film at a speed of 2.5 cm per second. The shutters were fixed in open position and the aperture selected to match film ASA value with lightning stroke brightness which is a function of range and intervening precipitation. Cameras were set on bases to elevate angle of view and facilitate aiming cameras in specific azimuthal directions. Timing was accomplished by activating small lights in the field of view of IRIG - B format time code.

3.10 STORM ELECTRICITY MEASUREMENTS FROM BALLOONS

In 1983 efforts were expanded to acquire in situ electrical measurements within severe storms. The two programs were headed by Dr. Tom Marshall of the University of Mississippi and by Dr. Arthur Few of Rice University. In both of these cooperative efforts, sensors were flown on balloons to measure electric fields inside storms. The programs operated from launch sites at Tuttle and Chickasha, and both also had successful attempts to intercept storms and launch balloons from mobile facilities.

3.11 STORM ELECTRICITY MOBILE LABORATORY

In a joint program with Dr. Roy Arnold of the University of Mississippi, a van has been equipped to function as a mobile electricity laboratory. Most of the instrumentation at the SEB is duplicated in the mobile laboratory. In addition, it has been equipped with a color TV recording system for storm cloud and lightning documentation. This provided quantitative electrical measurements and video recordings in a position that was roughly constant relative to the severe storms, in particular in the inflow region beneath the precipitation-free cloud base. The mobile laboratory was also used for ground truth measurements during U-2 overflights and to record data received from balloon-borne electric field meters flown into severe storms in another collaborative effort.

3.12 NSSL MOBILE LABORATORIES (NSSL-OU)

The Tornado Intercept Project (TIP) operated one chase van during the 1983 Spring Program. Emphasis was placed on obtaining verbal and photographic documentation of thunderstorm features (especially tornadoes). Thus, the equipment carried into the field included two 16-mm cameras, two 35-mm slide cameras, tripods, lenses, various other photographic accessories and supplies, portable tape recorders for verbal commentaries, and maps. Hand-held instruments (an anemometer, an aneroid barometer, and a psychrometer) were used to measure wind, pressure, and dry- and wet-bulb temperatures in and near mesocyclones.

The van was equipped with FM radio and a radio telephone. FM communications with the Nowcaster at NSSL were routed through a repeater located at the 440 m level on a KTVY television tower 40 km north of NSSL. Beyond the FM system's range (roughly 115 km from the repeater), the radio telephone was used whenever an open channel was available; otherwise, the Nowcaster was contacted by public telephone. Direct, short range, intervehicle communications, provided by a second FM radio channel, enabled the crew to exchange information with other field teams.

NSSL provided support to Dr. Howard B. Bluestein and the Oklahoma University intercept team for the deployment of TOTO.

3.13 NASA B-57B

The B-57B is a twin-engine jet aircraft originally designed for use as a high-speed low-altitude bomber capable of withstanding large vertical accelerations. The NASA aircraft was equipped to measure turbulence, wind, and temperature in addition to normal navigational parameters. Gust data were obtained from booms extending forward from the wing tip and the aircraft nose.

3.14 NASA U-2

A NASA U-2 carrying instrumentation from the Marshall Space Flight Center was flown over severe storms for making measurements of lightning. Instrumentation included optical detectors, spectrometers, electric field sensors, cameras, and a TV camera. The purpose of these flights was to determine the characteristics of lightning when viewed from above storms to facilitate the design of a satellite lightning mapper and to provide data on the lightning characteristics of severe storms.

3.15 NOAA RFC WP-3D

The WP-3D is a four-engine turboprop pressurized aircraft used for meteorological data collection. It is outfitted with a large variety of meteorological in situ and remote sensors. It has been widely used for weather reconnaissance (including Hurricanes) and air chemistry experiments, and recently for severe storm studies. For NSSL it was equipped with a gust probe; temperature, pressure, and humidity sensors; liquid and cloud water sensing instruments; particle size measurement systems (PMS Probes) which allow the determination of drop size measurement; and two radars. One radar was a 5 cm system located in the belly; it recorded reflectivity in all directions around the aircraft not near flight altitude. The other is a 3 cm Doppler radar located in the tail. This radar recorded RHI-type data transverse to the flight direction.

4. OPERATIONAL PERIODS, DAILY WEATHER SUMMARIES, AND NOTES ON OBSERVATIONS.

This section provides a summary for each day. Bar graphs for each data collection period, a weather summary, and pertinent remarks recorded by ground observers and aircraft personnel are presented.

The summaries are arranged chronologically beginning on 16 May 1983 and ending on 10 June 1983. The Stationary Automated Mesonetwork (SAM) and the Meteorological Tower are not included because observations from those sensors were nearly continuous throughout the research period.

Although most of the bar graph's legends can be easily deciphered, the following will assist those who are not familiar with the NSSL Spring Program.

NRO-DOP = Norman Doppler radar (Section 3.1)

CIM-DOP = Cimarron Doppler radar (Section 3.1)

NRO-VHF = Norman VHF Lightning Mapping System (Section 3.6)

CIM-VHF = Cimarron VHF Lightning Mapping System (Section 3.6)

ELF = Electric Field (Section 3.7)

SEB = Storm Electricity Building (Section 3.7)

WSR-57 = Norman WSR-57 radar (Section 3.2)

MOBILE

NSSL = Mobile Intercept Vehicles (Section 3.12)

U of M = Storm Electricity Mobile Laboratory (Section 3.11)

RAWINSONDE

EDM = Edmond site (Section 3.5)

TTS = Tuttle south site (Section 3.5)

FSW = Fort Sill west site (Section 3.5)

SNL = Shawnee site (Section 3.5)

AIRCRAFT

NASA's U-2 (Section 3.14)

NASA's B-57B (Section 3.13)

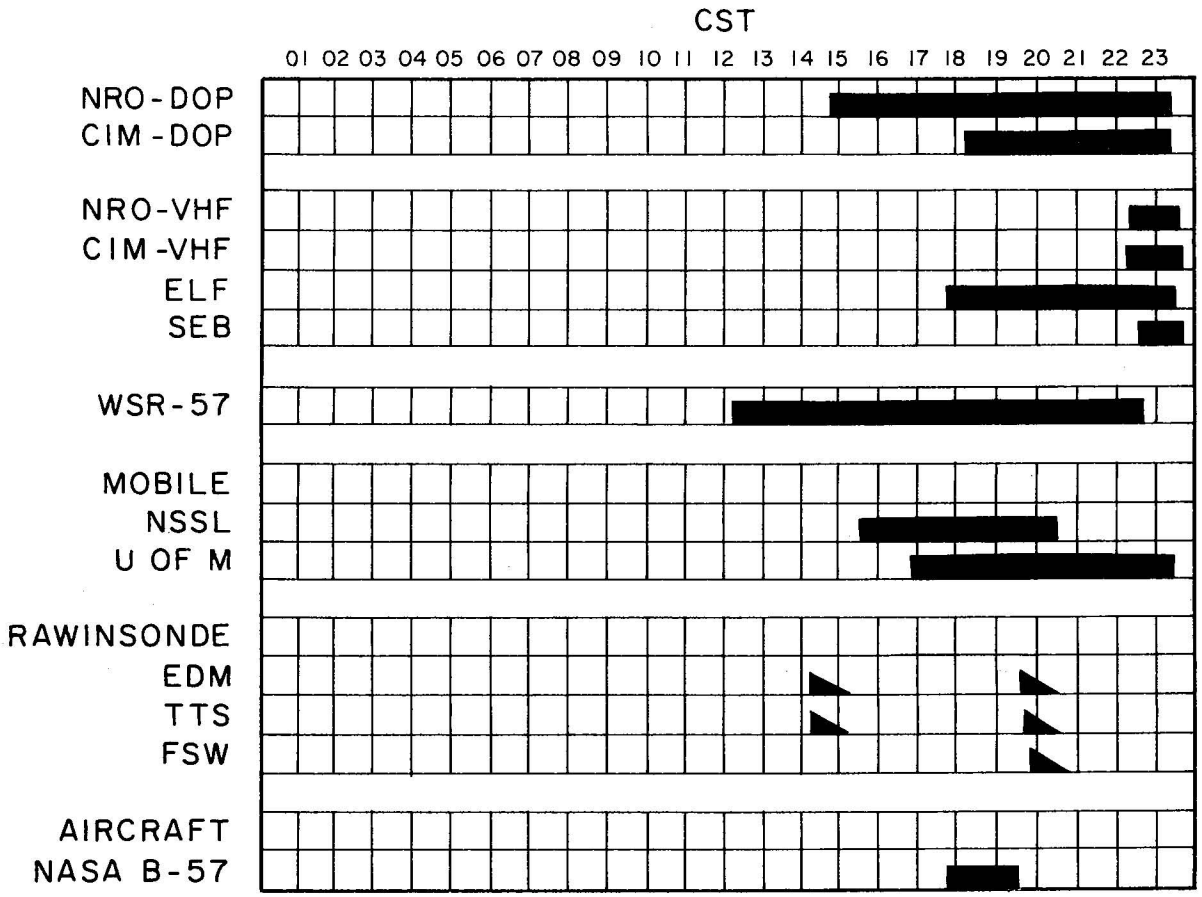
NOAA's WP-3D (Section 3.15)

4.1 16 May - Julian day 136

4.1.1 Weather Summary

The region was dominated by surface high pressure. No thunderstorm activity was forecast for this day.

4.2 17 May - Julian day 137



4.2.1 Weather Summary

A 500-mb low located over Colorado was accompanied by strong southwesterly flow aloft over Oklahoma. A surface low developed over eastern Colorado and moved eastward into western Kansas during the day. A Pacific front/dryline extended south from the low into the eastern Texas Panhandle. The dryline also moved east during the day and reached extreme western Oklahoma by evening. Moderate low level moisture extended up through southwest Oklahoma and there was convergence along the dryline; strong storms appeared likely despite a rather significant capping inversion. Dynamics were most favorable on the north end of the dryline, however, and thunderstorms, some tornadic, first developed in southwest Kansas and by late afternoon in extreme northwest Oklahoma near Gage. By evening the line of storms built further south. At least two mesocyclones appeared on radar, and a tornado occurred near Fairview. A new line formed ahead of the first and moved through central Oklahoma near 2200 with an associated gust front.

4.2.2 Notes on Observations

Lightning Mapping. Dual VHF mapping data were collected starting at about 2200 at Norman and Cimarron; both stations were observing the azimuthal sector 240-360 degrees. Very good data were obtained after 2217 when the sectors were changed to 180-300 degrees at Norman and to 120-240 degrees at Cimarron. The sector at Cimarron was shifted to 180-300 degrees for the period 2241-2248 and then returned to 120-240 degrees until termination of observations at 2321.

Photo Documentation. Strip-film cameras operated from 2230 to 2250 covering the view between 240 and 300 degrees.

NASA's B-57B aircraft flew along the leading edge of a line of thunderstorms about 170-180 km at 280-300 degrees from NSSL. Light to moderate turbulence was reported during this low-level (3000' or lower) flight.

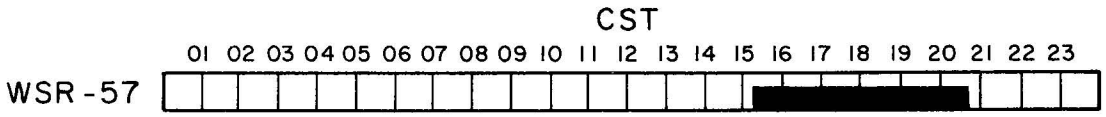
The NSSL Mobile Ground Observing team left at 1220, heading southwest. The dryline was intercepted near Duke at about 1530. Towering cumulus clouds on the dryline were entraining dry air and being sheared apart by the winds aloft. A small, low-precipitation, tilted, "dryline-type" storm formed near Willow at 1700 and moved rapidly to the northeast. The development of more potent storms appeared to depend on (suspected) changes in the boundary layer near sunset. The team followed a storm that formed near Elk City at 1830. By 1920 this storm was 10 miles north of Clinton and had developed circulation, apparent by the curved gust front that trailed from the main storm tower to our northeast. The team waited to be overtaken by other storms developing along the flanking line of the main storm. From Arapahoe a possible hail shaft was seen at 1930 and a lowered cloud base at 1955, both west of the team, before the intercept was terminated because of darkness.

4.3 18 May - Julian day 138

4.3.1 Weather Summary

A vigorous 500-mb low was located over central Kansas with a deepening surface low just to the east. The dry air intrusion swinging around the low had reached all but the eastern quarter of Oklahoma and was expected to move to the extreme southeast by mid afternoon. Severe weather was expected along the front from southern Missouri southwestward through northeast Texas.

4.4 19 May - Julian day 139



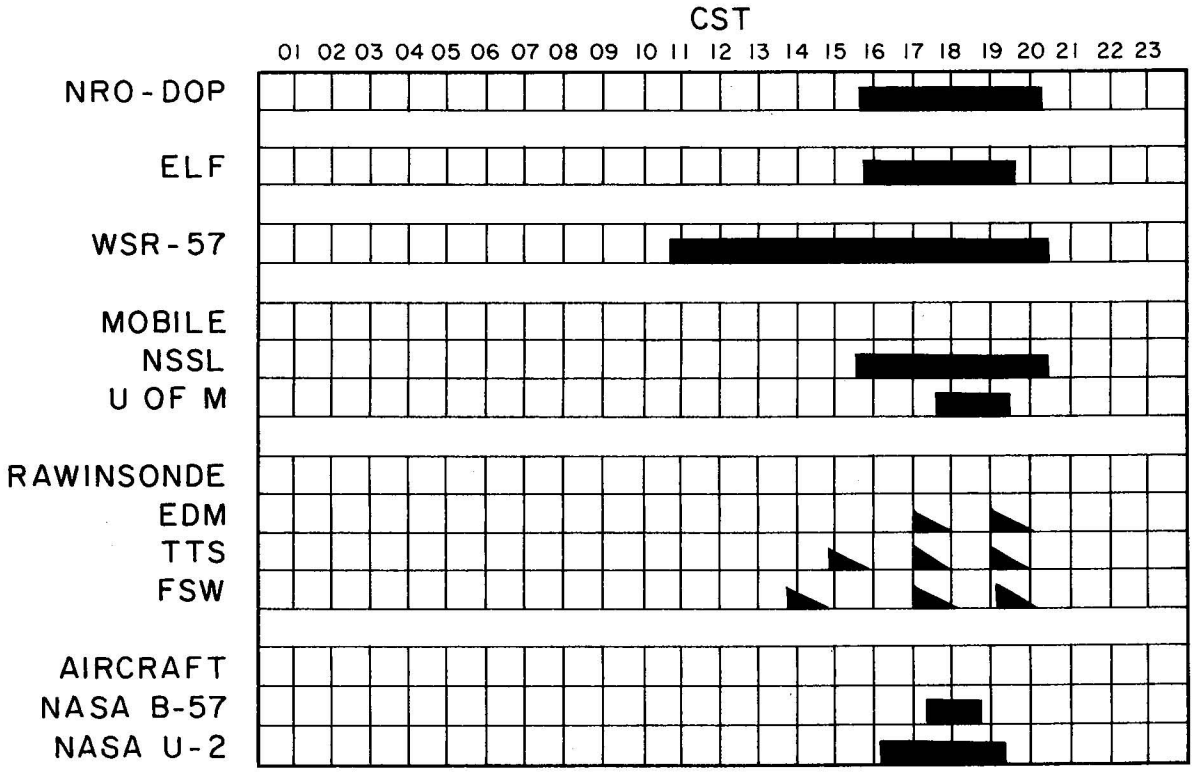
4.4.1 Weather Summary

The Kansas low moved rapidly to the Great Lakes region and the polar jet axis was centered near the Red River. A strong upper level wave was dropping southward through the Rockies. However, a major convective development was expected near the main surface front in southern Texas. A dryline developed in the eastern Texas Panhandle and west Texas. Some moderate storms did form along this line late in the afternoon despite relatively low atmospheric moisture content. Heavier storms developed west of Abilene, Texas, but stayed just south of Oklahoma. Very large storms developed near Del Rio and Austin, Texas, which evolved into an intense mesoscale complex in eastern Texas and Louisiana. Considerable thunderstorm and tornado damage was reported in the Houston area.

4.4.2 Notes on Observations

None.

4.5 20 May - Julian day 140



4.5.1 Weather Summary

In the morning, a surface low pressure center was south of the Rio Grande and an inverted trough extended northward into the western Texas Panhandle. A 500-mb low was just east of the Four Corners with a strong vorticity maximum in western New Mexico swinging to the east. Renewed severe thunderstorm activity developed in southern Texas during the late morning and moved into Louisiana by evening. By afternoon, a surface cold front had become evident from the Kansas-Oklahoma border southwestward to east central New Mexico. A dryline extended southward from the front into west Texas. A northeast-southwest line of thunderstorms developed in the early afternoon through the Texas Panhandle. As these storms moved eastward, tornadoes were reported in the southern part of the line in Texas. A severe thunderstorm affected the southwest corner of Oklahoma in the Altus area.

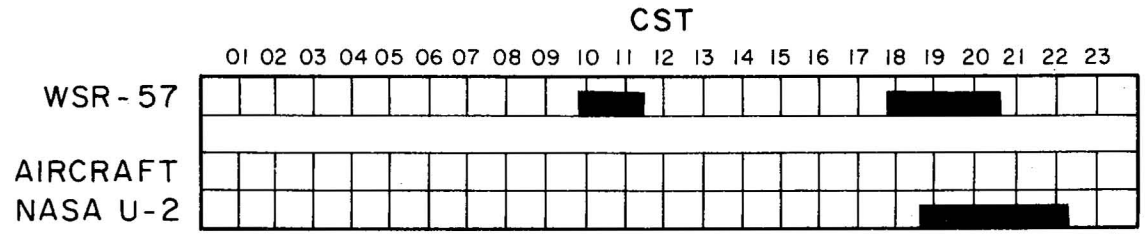
4.5.2 Notes on Observations

NASA's B-57B aircraft encountered light turbulence with several incidents of light-to-moderate turbulence in the thunderstorm area 95 km west-northwest of NSSL. Flight altitude was 3000' and below.

NASA's U-2 flew in northeast Texas and over a squall line west of NSSL.

The NSSL Mobile Ground Observing team departed NSSL at 1109. Two thunderstorms close together in a northeast-southwest configuration were intercepted in the Paducah-Matador-Turkey-Flomot region of west Texas, beginning around 1530. The storms were moving to the east-southeast. The team closed in on the northeast storm first and saw several short-lived wall clouds before cold air outflow surged ahead of the storm, eliminating chances for a significant tornado. The crew then turned south to intercept the other storm and saw a pickup truck which had received substantial dents from baseball-sized hail from this storm. This cumulonimbus had a tail-like cloud beneath its base on its southwest flank from 1650 to 1655. This storm also had short-lived wall clouds. The crew encountered 1-inch hail near Flomot at 1708 and two dust whirls with rotation in the arcus overhead at 1720. The gust front then surged ahead of this storm also. The team headed south in search of other storms but the closest ones were near Lubbock, out of range. On the way home, an intense storm was observed near Paducah. The storm had an extensive arcus cloud which apparently demarked strong outflow. Continuous and vivid lightning was observed beneath the arcus at dark.

4.6 21 May - Julian day 141



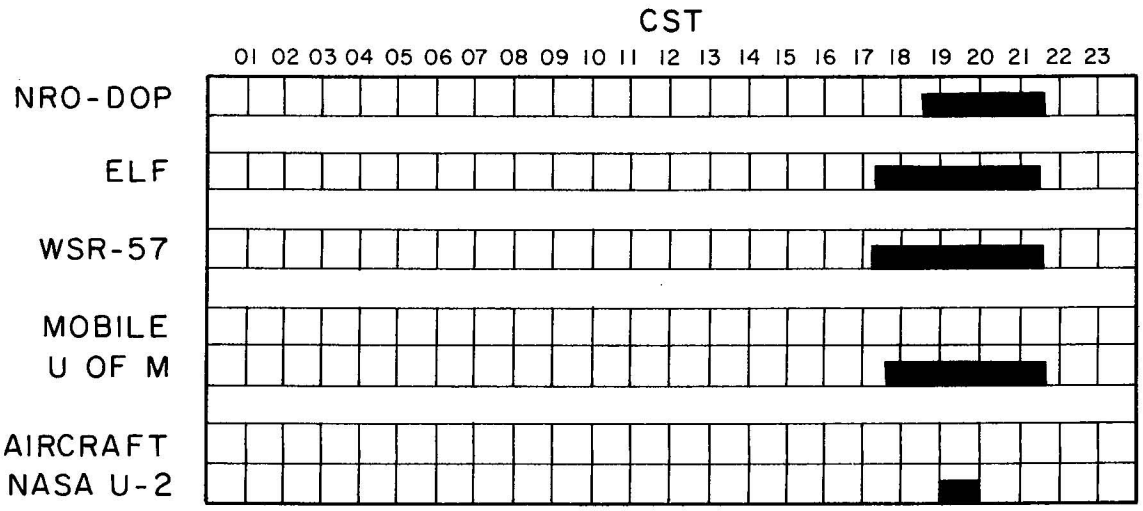
4.6.1 Weather Summary

An upper level trough extended from the Oklahoma Panhandle to southwest Texas. The surface front was in eastern Oklahoma; a low-level moist axis extended from eastern Texas northeast to Tennessee. Severe weather was expected to be south and east of Oklahoma.

4.6.2 Notes on Observations

NASA's U-2 orbited storms in the Fort Smith area.

4.7 22 May - Julian day 142



4.7.1 Weather Summary

A moderate perturbation at 500 mb was located in southwestern Colorado and moving southeastward. A small comma cloud, as observed by satellite, associated with the disturbance could be tracked southeastward during the day. By afternoon a well-developed surface low was just south of southwestern Oklahoma. Severe thunderstorms developed in southwestern Oklahoma and southward into Texas. Tornadoes were reported in north central Texas.

4.7.2 Notes on Observations

NASA's U-2 flew along a northeast-southwest line of thunderstorms that extended from east of NSSL to the Fort Sill area. Primary area of interest was southeast of Wichita Falls.

4.8 23 May - Julian day 143

4.8.1 Weather Summary

The 850 mb flow was northerly as far south as Abilene, Texas, and dew point temperatures were less than 7°C over Oklahoma at 0600. These values decreased to 3°C by 1800 as high pressure established itself over Oklahoma and northerly winds pushed south to the Gulf Coast.

At 500 mb a short wave trough was to the east of Oklahoma City at 0600. This system continued an eastward movement into eastern Arkansas by 1800. Northerly flow was well established over Oklahoma.

At 0600 a surface high pressure area centered in northern Kansas dominated Oklahoma. The cold front at the leading edge of this cooler and drier air extended from Memphis, Tennessee, to near Del Rio, Texas. Temperatures varied from 17°C at Tulsa to 9°C at Gage. During the day northerly winds continued to feed drier air into Oklahoma resulting in clear skies except for a small patch of cumulus near the Red River.

4.9 24 May - Julian day 144

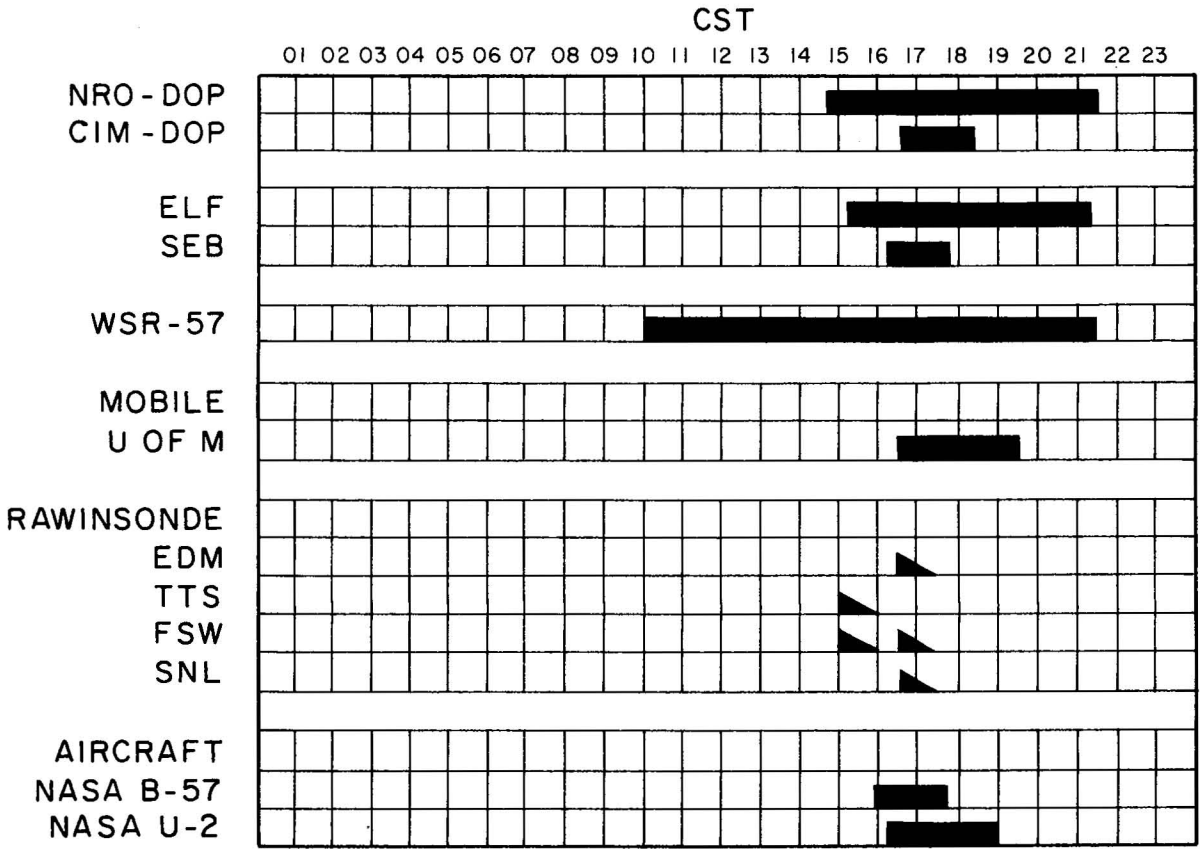
4.9.1 Weather Summary

The 850 mb moisture content remained low over most of Oklahoma during this period except for a small increase in dew point temperatures in the Texas Panhandle. There, weak southerly flow began to tap the Gulf moisture.

At 500 mb the northwesterly flow pattern continued over most of the central United States.

At 0600 a surface high was centered in northern Arkansas and return flow was beginning in western Oklahoma. The air over Oklahoma was relatively dry; surface dew points were 10°-12°C. Dew points of 15°C or more were restricted to south Texas. A trough began to form in the Texas and Oklahoma Panhandle region by evening. A line of thunderstorms formed from Lubbock northward to Dodge City by 1630. These thunderstorms developed into a Mesoscale Convective Complex (MCC) extending from Gage to Childress by 2000.

4.10 25 May - Julian day 145



4.10.1 Weather Summary

At 850 mb moisture increased in the southerly flow and dew points of 10°C were approaching the Red River by 1800. At 500 mb the flow remained northerly all day.

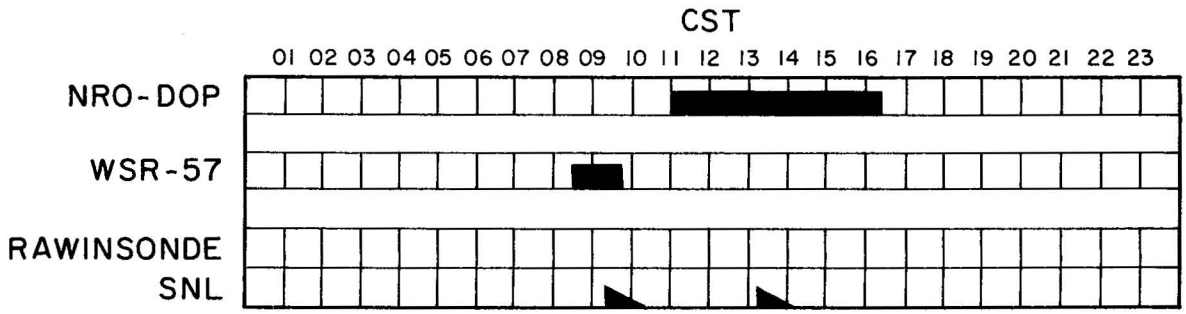
At 0600 the remnants of the surface high had moved to southeast Arkansas, and a cold front extending from St. Louis to Joplin to Wichita to Dodge City was moving southward. This cold front entered northern Oklahoma at about 0900 as southeasterly winds brought 14°C dew points into central Oklahoma. Thunderstorms developed on the front after 1400 as the front passed through Tulsa and Oklahoma City, hanging back to the west in the vicinity of Clinton. By 1630 a strong storm had developed between Norman and Ada. The line of thunderstorms moved southward at about 30 knots to near the Red River by 2100. At the same time a mesoscale complex had formed covering the Texas and Oklahoma Panhandles. This storm moved steadily eastward into western Oklahoma by midnight.

4.10.2 Notes on Observations

NASA's B-57B flew a low-altitude mission on a storm cell 60 km east of NSSL and stayed with the cell as it moved southward into the Ada-Ardmore area. Occasionally heavy rain was encountered. Turbulence was light, and several moderate turbulence encounters were reported.

NASA's U-2 overflew storms being sampled by the B-57B. At about 1800 occasional moderate turbulence was encountered above the thunderstorm, forcing a flight path deviation; the area was avoided on subsequent overflight. The U-2 assisted with communication with the B-57B because the B-57B went to altitudes below radio (and radar) contact range. The storm electricity chase vehicle observed the B-57B during its flight.

4.11 26 May - Julian day 146



4.11.1 Weather Summary

The 850 mb winds were westerly over most of Oklahoma at 0600, and the dry air was over eastern Oklahoma. By late afternoon all winds in Texas and Oklahoma were light and southerly, but the main moisture remained in southern Texas.

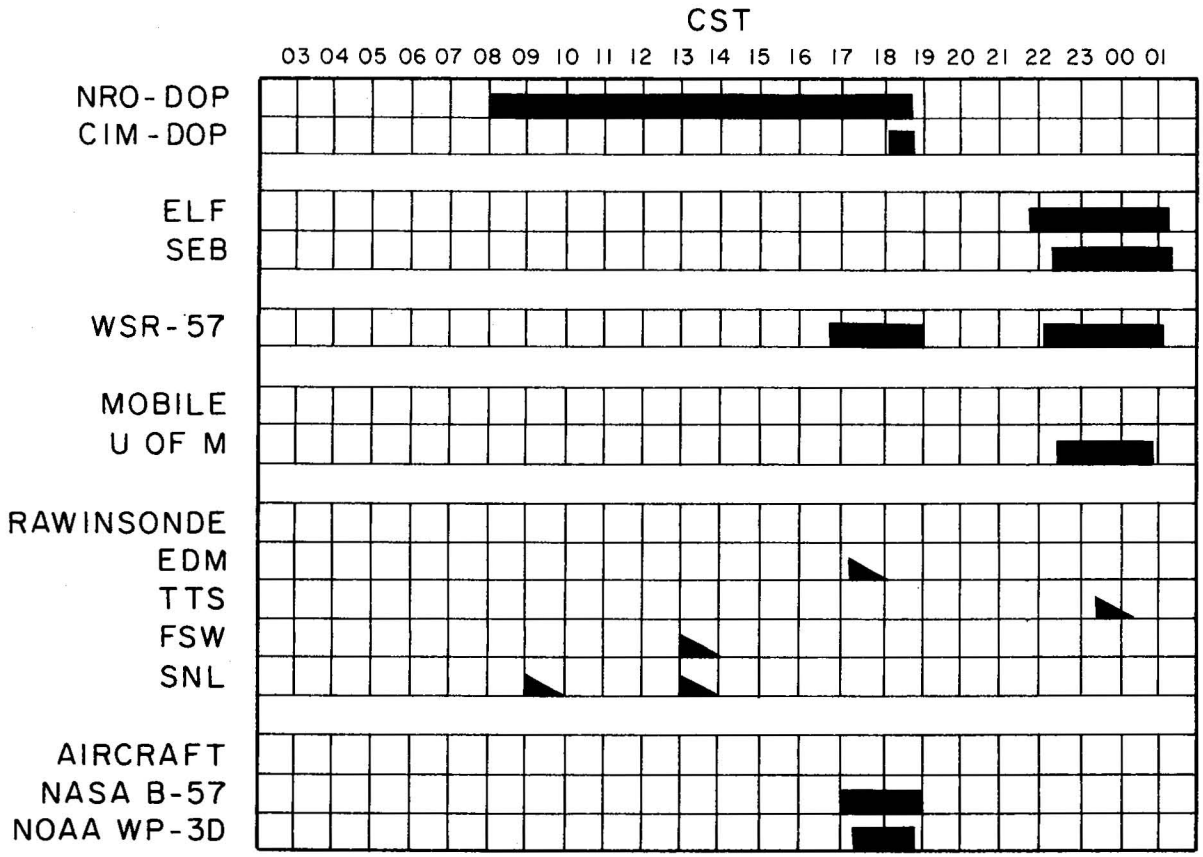
At 500 mb the winds remained northwesterly. The major downstream trough was still in the eastern United States with ridging to the west of Oklahoma.

The mesoscale thunderstorm convective complex that formed in the Texas-Oklahoma Panhandle on the 25th moved eastward and was found at 0600 in the vicinity of Enid-Oklahoma City-Fort Sill-Wichita Falls. The strongest activity was along the old quasi-stationary front just south of the Red River. By 1800 the only thunderstorm in the state was east of McAlester.

4.11.2 Notes on Observations

None.

4.12 27 May - Julian day 147



4.12.1 Weather Summary

At 850 mb the southerly winds increased at 0600, bringing about 10°C dew points over Oklahoma. Dew points continued to increase during the day and were 16°C at 1800. The winds at 500 mb remained northwesterly during the day.

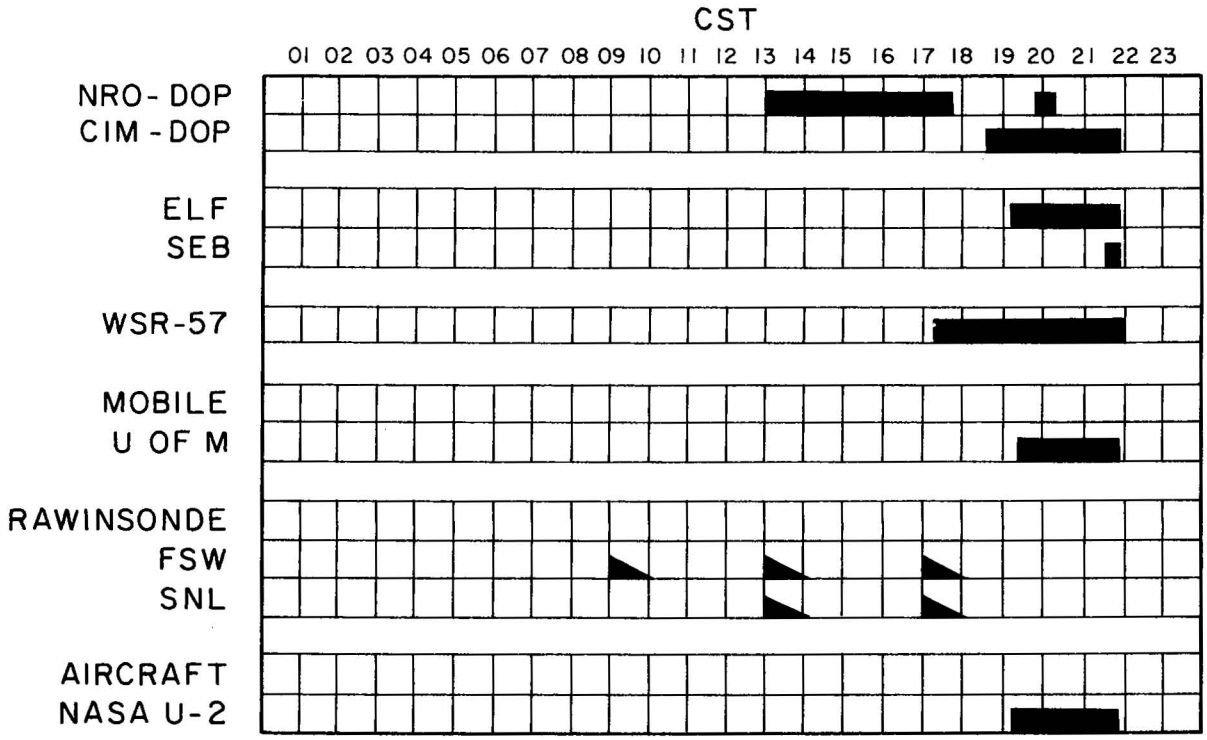
At 0600 a quasi-stationary front extended N-S from south of McAlester to the vicinity of Ponca City, thence northward to west of Topeka. Very warm moist unstable air was streaming northward west of the front into a low-pressure area west of Omaha, Nebraska. Thunderstorms were along a trough line intersecting the front and extending from Des Moines to Topeka, to Dodge City, to Amarillo, to Lubbock. These diminished during the morning, and by noon there was a small cell west of Kansas City, a small cloud area in the vicinity of Tulsa, and some clouds south of Lubbock. By 1500 nearly clear skies prevailed over Oklahoma but thunderstorms began forming along a line from Topeka to Salina to Garden City. They formed a MCC by 1930 and were moving southward, penetrating most of Oklahoma's northern border. A few storms had developed to the east of Oklahoma City; these storms did not develop into severe storms as the MCC moved southward. The MCC extended east-west across Oklahoma, and the leading edge was past Oklahoma City by midnight.

4.12.2 Notes on Observations

Strip-film cameras recorded lightning within the sector 270-330 degrees from 2250 to 2310. Intermittent observations were made during the period 0001 to 0005 (Julian day 148) in the sector 240-300 degrees. The sector 210-270 degrees was covered during the period 0006 to 0022.

Both NASA's B-57B and NOAA's WP-3D aircraft investigated a thunderstorm near Chandler, Oklahoma, from about 1730 to 1820. The storm was reported to have had 3/4" hail associated with it. The WP-3D flew at 23,000 msl and the B-57B between 2500 and 3500 msl. After the storm decreased in intensity about 1820, the WP-3D returned to base and the B-57B began a series of flybys near the NSSL Tower Facility. These were completed by 1840 and the aircraft then returned to Tinker AFB.

4.13 28 May - Julian day 148



4.13.1 Weather Summary

The 850-mb winds were variable over Oklahoma with mostly light northerly winds at 0600. Dew points over most of the state were 7°C or less.

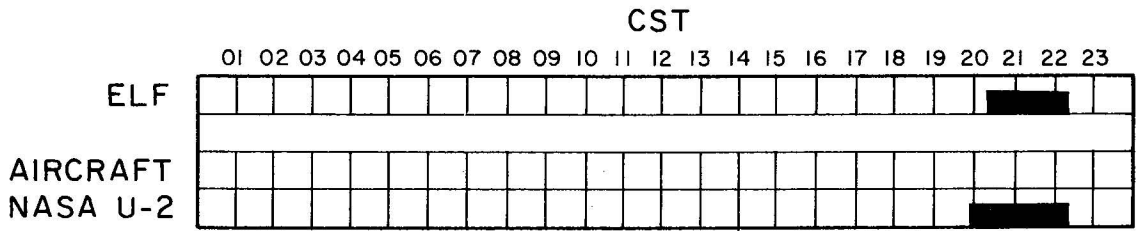
At 500 mb northwesterly flow continued to dominate the central United States while the major long wave trough remained in the eastern United States.

The MCC that moved into Oklahoma from the north on the 27th covered Oklahoma except in the Panhandle. Storms that had formed in eastern Colorado and eastern New Mexico were beginning to move in from the west. In addition, activity along a cold front (or convergence line) began to intensify and by 1630 a line of thunderstorms was indicated from Alva westward to northeast New Mexico. The influx of moist, unstable air borne on southerly winds into these storms allowed for their continued growth as they moved southward at about 20 knots. At 2130 the line extended from near Tulsa to just north of Oklahoma City to near Altus. The line passed Fort Sill near midnight.

4.13.2 Notes on Observations

NASA's U-2 aircraft circled and also overflew storms 320/165 km and 315/125 km from NSSL. The aircraft stayed with the latter storm as it drifted southward. Lightning was reported by the pilot.

4.14 29 May - Julian day 149



4.14.1 Weather Summary

At 850 mb the winds continued to have a northerly component over Oklahoma, bringing even drier air into the state. Dew points had dropped to 4°C at 0600 and to 3°C by 1800.

At 500 mb northerly winds were also recorded. The main jet axis extended from central North Dakota to central Missouri to northern Mississippi. Negative vorticity advection dominated Oklahoma and in combination with the dry air at low levels resulted in a dearth of convective activity.

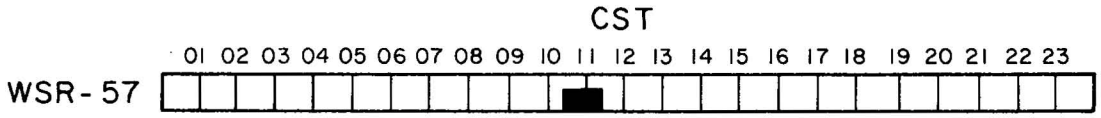
At 0600 the outflow boundary of the Saturday MCC (also indicated as a cold front) extended from northern Arkansas to McAlester to Wichita Falls to Lubbock. The major low in central Michigan brought northerly flow to Oklahoma and with it cooler and drier air. By 1800 a few dew points in northern Oklahoma had already fallen to near 10°C.

The early morning (0600-0800) thunderstorm east of a Tulsa-McAlester line moved out of the state by 1100. In the west, near sundown, thunderstorms formed in the extreme western Texas and Oklahoma Panhandles.

4.14.2 Notes on Observations

NASA's U-2 flew near the Texas-New Mexico border.

4.15 30 May - Julian day 150



4.15.1 Weather Summary

At 850 mb air remained dry over Oklahoma. At 0600 a short wave at 500 mb was moving southeastward across the Texas Panhandle in the west-northwesterly flow around a vortex located over the Great Lakes.

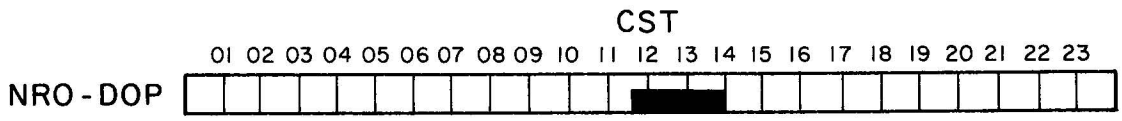
At the surface an inverted trough was located in the Texas Panhandle with a southward-moving cold front extending from the Panhandle east-southeastward through extreme northern Texas. Air in Oklahoma during the morning was relatively dry; dew points were near 10°C and winds were northeasterly. More unstable air existed to the southwest and west of Oklahoma; high surface and 850 mb dew points extended northward into the Texas Panhandle. In the morning hours a large rain area, with a few embedded thunderstorms, was located in central Oklahoma. It slowly drifted southeastward during the day. Intense thunderstorm activity was restricted to the west Texas area late in the day.

4.16 31 May - Julian day 151

4.16.1 Weather Summary

The surface front moved southward to southern Texas; a high pressure ridge was over the Texas Panhandle at mid-morning. Winds over Oklahoma were northerly and light, and dew points over the state were near 10°C. All sections of the state except the northeast remained under low overcast to broken clouds throughout the day. The cold air north of the front was quite deep, extending up to about 3 km.

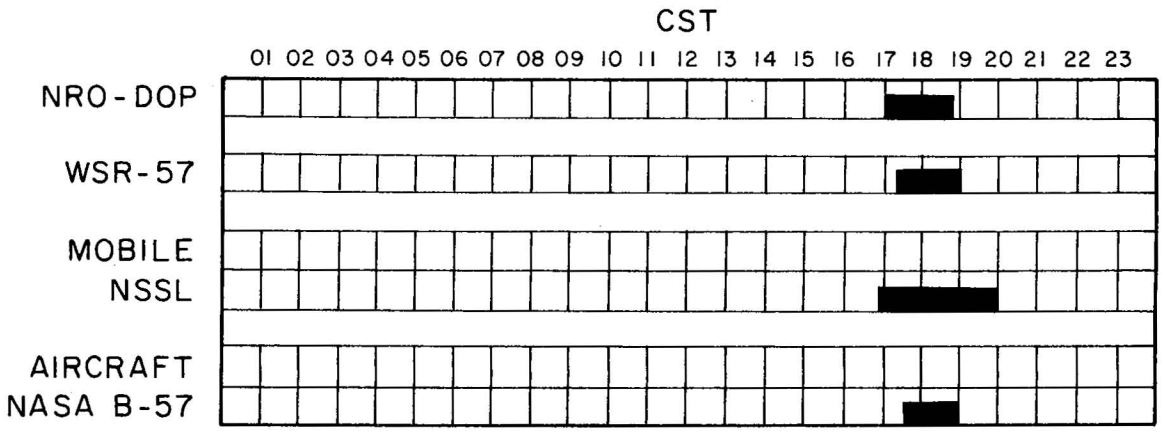
4.17 1 June - Julian day 152



4.17.1 Weather Summary

In the upper levels the nearest significant short wave was off the coast of California. Air over Oklahoma was still quite stable. Dew points were low at the surface, and a ridge of high pressure extended over the southeastern portion of the state. During the day a surface pressure trough developed along the Texas-New Mexico border, extending southward from a low in eastern Colorado. Moisture return had not yet begun over southwest Texas even by late in the day. No significant convective activity occurred in Oklahoma during the day.

4.18 2 June - Julian day 153



4.18.1 Weather Summary

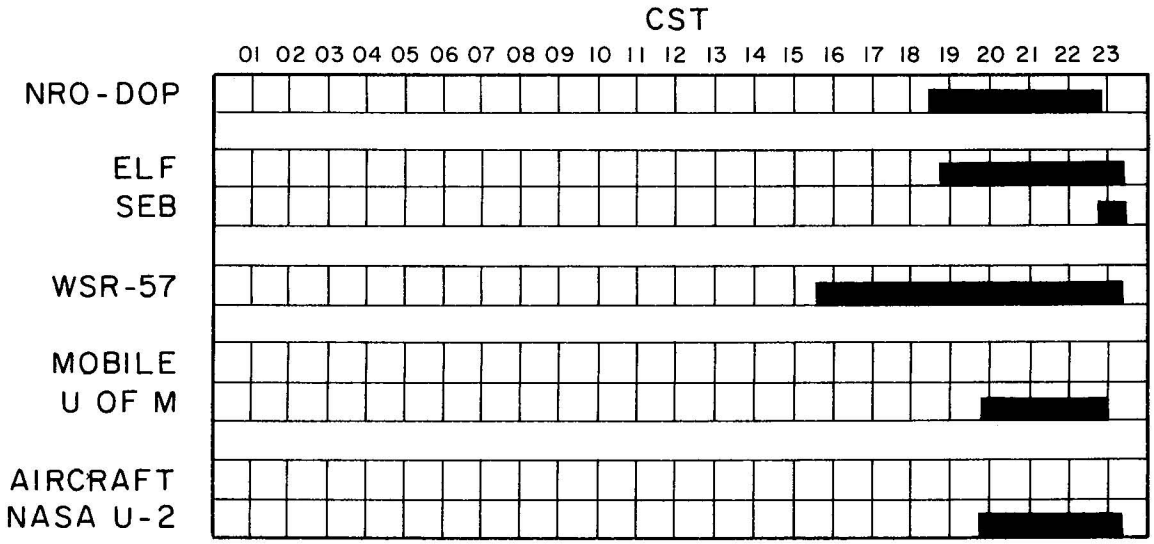
At 850 mb a moist axis extended from southwest Texas north-northwestward over central Oklahoma. The nearest significant short wave at 500 mb was located over the Western Plateau region. Surface moisture had returned during the night. Strong southerly winds and dew points of 16 - 18°C were over Oklahoma by mid-morning. At the surface a low-pressure center was located over southwest Kansas. A warm front lay east-west across central Kansas, and a dry line extended southward from near Dodge City to Lubbock to Midland. Soundings were all strongly capped in the morning, and this changed little during the course of the day. Convergence along the dryline was not strong enough to break the cap, and large-scale upward motion was apparently occurring only farther to the north over Colorado and Kansas. The nearest deep convection formed in eastern Colorado in the late afternoon and moved eastward across Kansas during the night. Skies remained cloudy over most of Oklahoma except the western one-fourth at mid-day and the western half by late afternoon.

4.18.2 Notes on Observations

NASA's B-57B made several low-altitude turbulence runs near the NSSL Tower Facility. Flight altitude was 1800 to 2700 ft msl. At upper levels moderate turbulence was experienced.

The NSSL Mobile Ground Observing team left Norman at 1143 and intercepted a warm front near Medicine Lodge, Kansas, at 1650. Although towering cumulus clouds were observed south of the front from 1845 to 2000, storms failed to develop.

4.19 3 June - Julian day 154



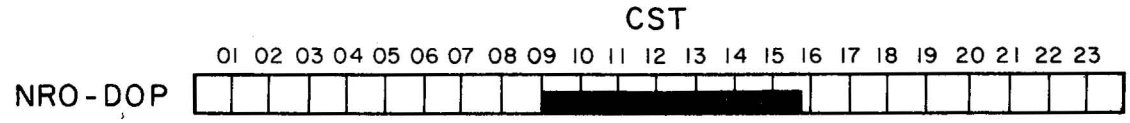
4.19.1 Weather Summary

At 850 mb considerable drying had occurred over central and northern Oklahoma, but moisture remained over the Texas Panhandle and western Kansas. Flow at 500 mb was west-southwesterly and a weak short wave moved eastward across western Oklahoma. A cold front extended across Oklahoma from near Bartlesville to near Wichita Falls, Texas. Dew points southeast of the front were 21°C as the front moved slowly southeastward ahead of 10-15 knot northwesterly winds. Soundings again indicated a cap in the 800-750 mb layer, but it was somewhat weaker than on the previous day. In the late afternoon a line of strong thunderstorms formed along the front in southeast Oklahoma, the nearest being about 175 km southeast of Norman. The line moved slowly southeastward and dissipated during the late evening hours. Another small area of strong thunderstorms moved southeastward out of southwest Kansas in the cold air during the afternoon, but this area dissipated during the early evening 150-200 km north-northwest of Norman.

4.19.2 Notes on Observations

NASA's U-2 flew over storms in the vicinity of 135/220 km and near Paris, Texas.

4.20 4 June - Julian day 155



4.20.1 Weather Summary

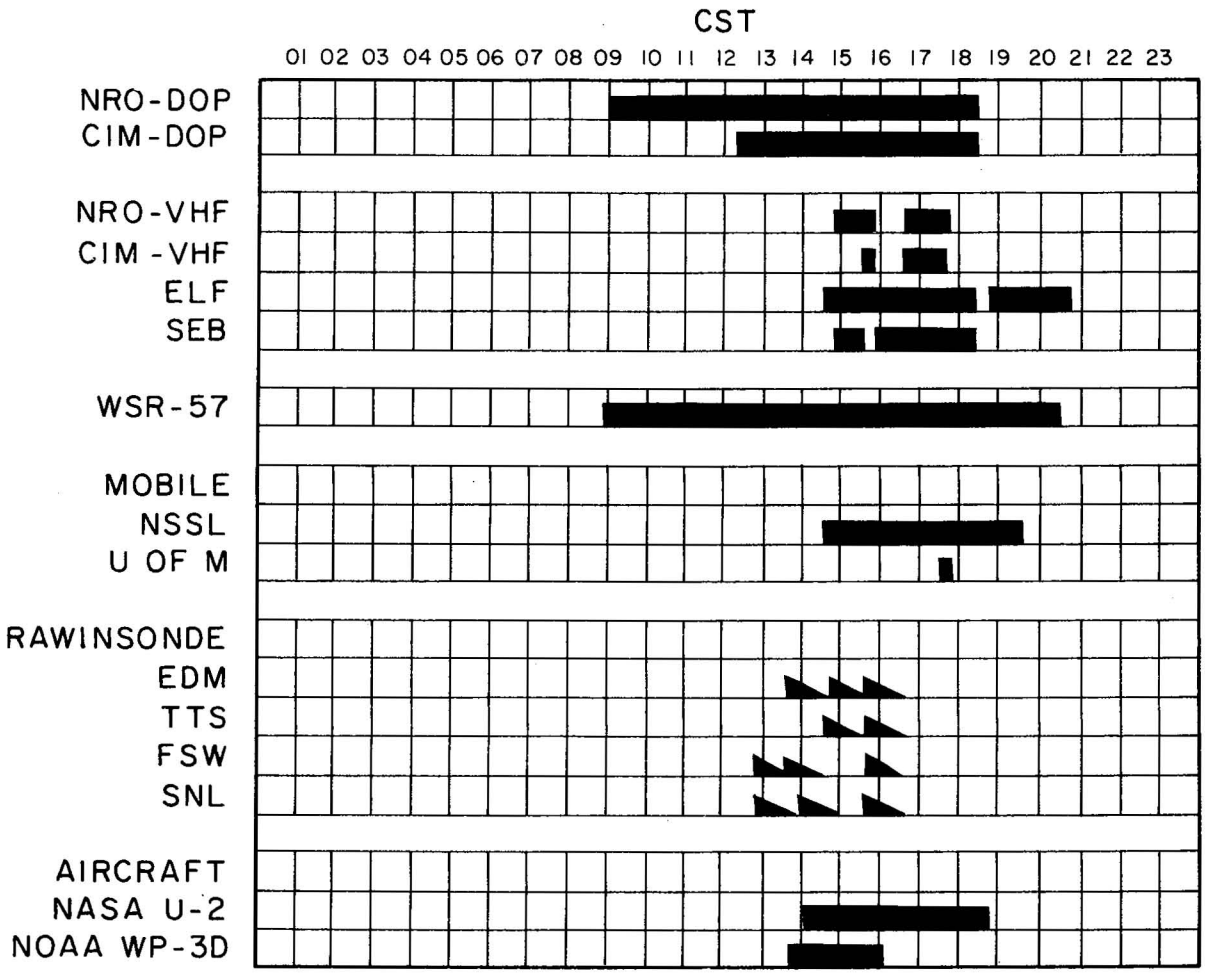
At 500 mb a weak short-wave axis was over eastern Oklahoma and a stronger one over western Arizona. At mid-morning a cold front extended from southwest Arkansas to central Texas and became indistinct over west Texas. The dry air had not pushed far southward with this frontal passage over Oklahoma. Winds were light northeasterly, and dew points ranged from 13°C in the northwest to 20°C in the southeast. A ridge of high pressure extended east-west across the state, and a north-south dryline was located along the eastern New Mexico border. Soundings were marginally unstable in the Oklahoma area but potentially very unstable in the Amarillo-Midland-Stephenville triangle.

In the early afternoon, thunderstorms began in the Abilene, Texas, area and in Texas just east of the New Mexico border within and just south of the Panhandle. These storms were severe in Texas but none moved into Oklahoma.

4.20.2 Notes on Observations

None.

4.21 5 June - Julian day 156



4.21.1 Weather Summary

At 850 mb dew points were quite high except for a dry area in north-central Texas which had apparently resulted from outflow from a convective complex during the night. At 500 mb a vorticity maximum was moving eastward out of southeast Wyoming and a much weaker short wave was located in western New Mexico. At mid-morning a surface cold front extended east-west across northern Oklahoma. A band of rain extended from just south of Ponca City to near Gage, then south-southwestward to near Childress, Texas. An outflow boundary from the area of rain in western Oklahoma was located from 50 miles west of Oklahoma City to south of Altus to south of Childress. An inverted pressure trough extended from near Stephenville, Texas, northward toward Altus. Dew points in Oklahoma ranged from 16°C to 19°C and winds were light from the southeast over the southeastern two-thirds of the state.

Strong thunderstorms started at about noon along the cold front and outflow boundary in an east-west line in an area north and northeast of Norman. These moved slowly southeastward during the day, and quite strong cells developed

intermittently near the west end of the line. Another area of weaker activity with a few moderate thunderstorms existed to the southwest and west of Norman during the afternoon. In the late afternoon a more organized line (oriented northeast-southwest) formed having its northern end about 100 km south of Norman. Much of this activity was north of the cold front which had moved southward through the state during the afternoon. Activity may have been influenced by an upper level wave identified with a weak vorticity maximum located in northeastern New Mexico on the 1800 analysis.

4.21.2 Notes on Observations

Lightning Mapping. Norman began recording at 1453 in the sector 0-120 degrees, and changed at 1458 to 060-180 degrees. Cimarron began observations at 1534 in the sector 120-240 degrees. Both stations ceased recording at 1558. During the period, 1638-1739 observations were made as Norman and Cimarron covered the sectors 180-300 degrees from each station.

NASA's U-2 flew over storms located about 095/110 km from NSSL. At 1600 the U-2 was over a reported tornado (Ground Observer report). Toward the end of the mission, the aircraft was working cells due south of NSSL.

NOAA's WP-3D flew at 20,000 ft near a storm located at 090/110 km, which produced hail and a possible vortex.

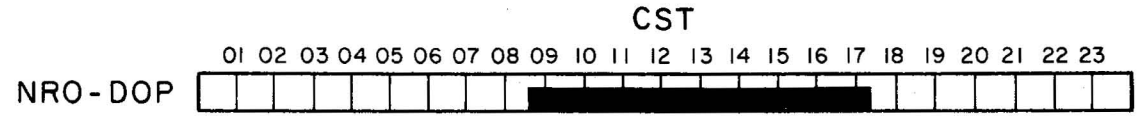
The NSSL Mobile Ground Observing team headed south from Norman at 1233. They stopped in the Arbuckles at 1400 to watch some towers go through their life cycles and to await more intense activity. At 1440 they began pursuit of a storm to the southwest which was intercepted at Wilson at 1518 just as it was dissipating. The team saw some interesting striations in the base before it "rained out" and from 1522-1524 two high-based, but quite long, funnels emanating from the (by then) orphan anvil of the storm were observed. The team headed south and intercepted a storm near Bowie, Texas, at 1730. This storm had an extensive arcus cloud, part of which was very low and ominous looking. They were overtaken by very heavy rain and high winds at 1810. The team observed a funnel cloud near St. Jo, Texas, at 1900. The funnel was on the gust front near the place where it arced back into the main body of the storm.

4.22 6 June - Julian day 157

4.22.1 Weather Summary

A large surface high was approaching Oklahoma from the west. Northerly winds and a stable atmosphere had overrun all the region.

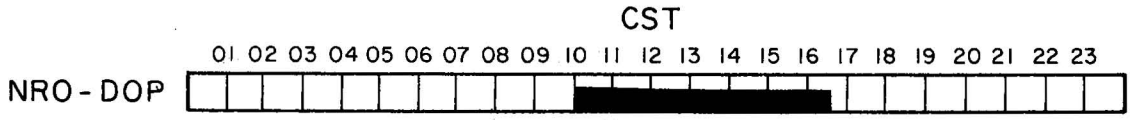
4.23 7 June - Julian day 159



4.23.1 Weather Summary

Surface high pressure was centered over the area. Conditions were relatively dry with light winds. A weak impulse traveling eastward across Kansas was not expected to effect Oklahoma. Fair weather cumulus formed in central Oklahoma during the afternoon, and thunderstorms developed on the eastern plains of New Mexico.

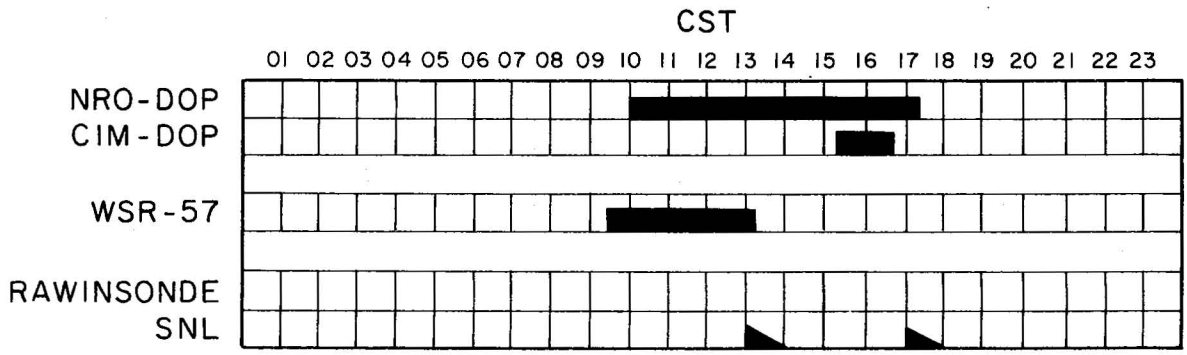
4.24 8 June - Julian day 159



4.24.1 Weather Summary

Surface high pressure was centered over eastern Oklahoma. Surface winds were light and southeasterly, and moisture was returning to the west. Winds aloft were west-northwesterly; the 500 mb ridge line was over the Rockies. The atmosphere was potentially unstable over the Texas Panhandle and west Texas (lifted index near -5). Thunderstorms developed off the mountains by early afternoon, intensified, and moved through eastern New Mexico to the western Texas Panhandle by evening. One small storm farther east entered western Oklahoma and dissipated by evening.

4.25 9 June - Julian day 160



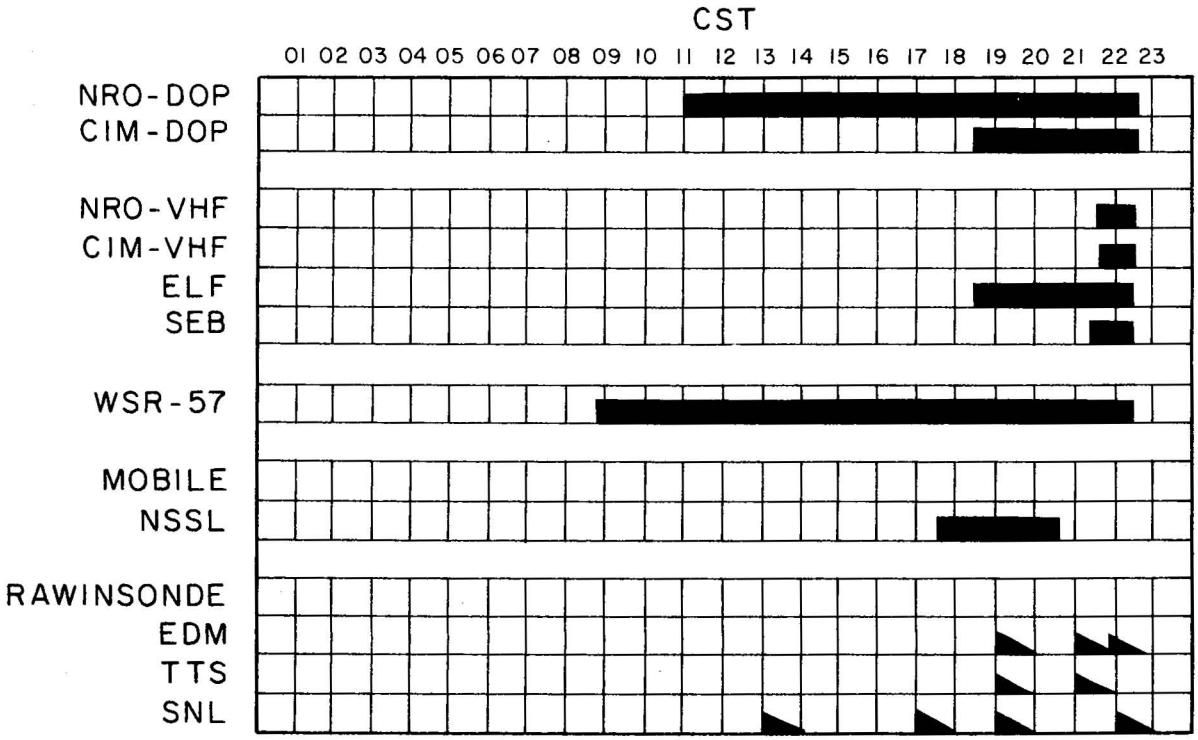
4.25.1 Weather Summary

Anticyclonic flow continued around a surface high centered to the east of Oklahoma, bringing moisture up from the south. Weak pertubations coming out of a trough in the southwestern United States were moving through a broad ridge at 500 mb over the region. Convection from the morning dissipated as it entered Oklahoma from the west. The atmosphere was once again most unstable to the west. Thunderstorms formed in the afternoon over the Rocky Mountains, the northeastern New Mexico plains, and west central Kansas. The storms appeared to be linked to jet streaks observed in the satellite photographs. Some thunderstorms affected extreme northwest Oklahoma by evening.

4.25.2 Notes on Observations

None.

4.26 10 June - Julian day 161



4.26.1 Weather Summary

A 500-mb low was located over Colorado, and an upper trough was swinging northeast out of our region in the morning. At the surface, a trough extended south from western Kansas to the western Oklahoma border. Another upper level impulse approaching from the west and moderately unstable conditions over Oklahoma set the stage for thunderstorm development later in the day. A line of strong thunderstorms developed early in the afternoon from the northeast Texas Panhandle to south central Kansas. This line gradually moved southeastward during the evening and produced a gust front in central Oklahoma at 2100. Mesocyclone signatures were noted near Elk City and Hinton.

4.26.2 Notes on Observations

Lightning Mapping. Norman recorded flashes in the sector 240-360 degrees during the period 2134-2232. Cimarron began coverage in the sector 180-300 degrees at 2134 and changed to 0-120 degrees at 2134 until observations ended at 2232.

The NSSL Mobile Ground Observing team departed at 1320, heading west. The team passed some towering cumulus near Elk City around 1530 and a cumulonimbus north of Erick near 1600. A storm with a very dark precipitation core and a long gust front was intercepted at Canadian, Texas, at 1730. The storm had a low wall cloud situated in a notch in the precipitation core to the northwest. This wall cloud appeared to be in rain-cooled air. The team was forced to move southwest to avoid heavy precipitation and went to the southwest edge of the storm near Miami. Here, were seen some eddies in the cloud base along the gust front, but the towers in this region soon died. On the way home small hail was encountered in the Texas Panhandle, and extensive rain and street flooding in Clinton.

ACKNOWLEDGMENTS

The authors are indebted to Ms. Ruth Wilk for typing and management of manuscript preparation. Drafting support of Messrs. Charles Clark and Robert Goldsmith and Ms. Joan Kimpel is appreciated.

APPENDIX A

The University of Wisconsin 1983 Boundary Layer Experiment

Boundary Layer Experiment 1983 (BLX83) was designed to study the interactions between daytime fair-weather cumulus clouds (cumulus humilis and cumulus mediocris) and the atmospheric boundary layer over land.

Oklahoma was selected as the site because of the support and Doppler radar coverage that the National Severe Storms Laboratory (NSSL) in Norman, Oklahoma, could provide. This site was climatologically expected to have about 3-4 days per week of fair-weather clouds in the spring.

A primary field site just southeast of Chickasha, Oklahoma, was selected because of its terrain, electrical power availability, location relative to airways, and dual-Doppler radar coverage.

The abbreviated names for the experiments conducted are as follows:

EXPERIMENT NUMBER	ABBREVIATED NAME
1	Cloud base
2	Entrainment zone
3	Terrain mapping
4	Refractivity & storm
5	Evening transition
6	Nocturnal
7	Turbulence
8	Landsat comparison

The BLX83 observation period of May 25 through June 18 was selected to overlap with NSSL's annual spring observing program for severe weather (May 15 - June 10).

For additional information, contact

Dr. Roland Stull
Meteorology Department
University of Wisconsin
1225 W. Dayton Street
Madison, Wisconsin 53706

APPENDIX B

NSSL Doppler Radars

Basic radar system characteristics are given in Table B.1. These represent the system configuration during the 1983 data acquisition period. The receiver noise level is subject to some variation and is usually supplied for the particular data set of interest. The gate shift corrections along with ranging values for each PRT are given in Table B.2. These values are derived by pointing the radar antenna at known isolated ground targets and averaging the integrator, hardwired velocity, and width estimator values for 50 samples at each range interval. Usually these values are considered mid-point values for gate 1. Additionally, the antenna-pointing correction logic is given in Table B.3. The beam-pointing errors are derived from data collected by scanning the sun in both azimuth and elevation at 30-minute intervals for several hours and calculating the difference relative to the position of the sun.

As in the past, it is recommended that the status of the integrator and the hardwired velocity calculator be examined prior to extensive analysis of a particular data set. Quality control routines designed to perform basic hardware checks as well as to detect errors that are erratic and infrequent, are available upon request.

Table B.1 NSSL Doppler Radar Characteristics - Spring 1983

PARAMETER	CIMARRON (CIM)	NORMAN (NRO)
Antenna		
Shape	Parabolic	Parabolic
Diameter	9.15 m	9.15 m
Half-Power Beamwidth	0.85 deg.	0.81 deg.
Gain	46 dB	46.8 dB
First Side-Lobe Level	21 dB	21 dB
Polarization	Vertical	Vertical
RMS Surface Deviation	2.5 mm	2.8 mm
Transmitter		
Wavelength	10.94 cm	10.52 cm
Frequency	2735 MHz	2850 MHz
Peak Power	500 kW	750 kW
Pulse Width	1 μs (150 m)**	1 μs (150 m)**
Pulse Repetition Time (PRT)	See below	See below
Receiver		
System Noise Figure	4 dB	4 dB
Transfer Function	Doppler - linear Intensity - logarithmic	Doppler - linear Intensity - logarithmic
Dynamic Range	80 dB	80 dB
Bandwidth: 3 dB; 6 dB	0.6; 0.85 MHz	0.6; 0.85 MHz
Receiver Noise Level	-105 dBM	-108 dBM

Basic PRT	Unambiguous CIM/NRO Velocity	Velocity Range	Velocity Range Increment	Intensity Max Range*	Intensity Range Increment*	Digital Tape Density
768 μs	35.6/34.2 ms^{-1}	115 km	150 m	460 km	600 m	744 bpi
922 μs	29.7/28.5 ms^{-1}	138 km	180 m	552 km	720 m	620 bpi
1075 μs	25.4/24.5 ms^{-1}	161 km	210 m	644 km	840 m	531 bpi
1229 μs	22.3/21.4 ms^{-1}	184 km	240 m	736 km	960 m	465 bpi

* Values given are for batch; in equi-spaced mode the intensity range coverage is same as velocity.

** In wide-pulse mode, pulse width is 3 μs or 5 μs; PRT is three times one of the above four basic PRT's (usually 768 μs). Equi-spaced pulses only.

TABLE B.2

1983 DOPPLER RADAR SLANT RANGE AND GATE SHIFT CORRECTIONS

1983 Doppler Radar Slant Range

PRT	Resolution	Gate Length	NRO Range to Gate 1	CIM Range to Gate 1
768 N	± 75 m	150 m	-440 m	-720 m
922 N	± 90 m	180 m	-380 m	-780 m
1075 N	±105 m	210 m	-380 m	-750 m
1229 N	±120 m	240 m	-290 m	-930 m
768 E	±300 m	600 m	-890 m	-1170 m
922 E	±360 m	720 m	-1010 m	-1410 m
1075 E	±420 m	840 m	-1010 m	-1170 m
1229 E	±480 m	960 m	-1010 m	-2130 m
768 W	±225 m	450 m	-740 m	-1320 m

N = Normal Mode
E = Expanded Integrator
W = Wide Pulse

1983 Gate Shift Corrections

NRO - Normal	INT (1) = INT (1) VEL (1) = VEL (3) STD (1) = STD (3)
CIM - Normal	INT (1) = INT (1) VEL (1) = VEL (3) STD (1) = STD (4)

INT = Integrator
VEL = PP Velocity
STD = PP Width Estimator

TABLE B.3

1983 ORIENTATION ADJUSTMENTS FOR NSSL DOPPLER RADARS

NRO

Elevation Error = $-0.01\phi°$

Azimuth Error = $-0.85° \cos(\theta+10°)$

ϕ and θ are the indicated elevation and azimuth angles.

CIM

Elevation Error = $-0.1°$

Azimuth Error = $-0.3° \sin 2(\theta-20°) + 0.05$

Appendix C

NSSL Stationary Automated Mesonetwork (SAM)

C.1 Station Locations

The following is a list of NSSL stations used for the 1983 Mesonetwork during the research period.

1983 Mesonetwork

I.D.	No.	Name	Lat. N.	Long. W.	MSL Elev. Ft.*	County	Map Scale x 10^2
MWF	8301	NSSL	35°14'13"	97°27'43"	1175	Cleveland	1:240
COE	8303	Coltrane Road	35°29'45"	97°26'32"	1245	Oklahoma	1:240
NWH	8306	NW Highway	35°31'36"	97°33'36"	1278	Oklahoma	1:240
YUN	8307	Yukon N	35°33'48"	97°43'37"	1340	Canadian	1:240
MOO	8308	Moore	35°18'46"	97°30'43"	1205	Cleveland	1:240
WRS	8309	Will Rogers S	35°21'50"	97°36'02"	1243	Cleveland	1:240
WNW	8310	Will Rogers NW	35°26'07"	97°40'35"	1280	Canadian	1:240
TTE	8313	Tuttle E	35°18'18"	97°40'45"	1292	Grady	1:240
MUS	8314	Mustang	35°23'30"	97°45'29"	1360	Canadian	1:240
YSW	8315	Yukon SW	35°27'51"	97°48'38"	1337	Canadian	1:240
TTS	8326	Tuttle S	35°13'38"	97°51'12"	1273	Grady	1:240
CHK	8333	NSSL CHK	35°06'07"	97°57'43"	1148	Grady	1:240

* Add four feet to get the height of the instrument shelter.

C.2 Components of Sensor and Recording System Used in the 1983 SAM System

(1) Wind Speed

Specially calibrated weather service F-420-C rotating cup DC generator.

(2) Wind Direction

National Weather Service F-420-C splayed tail wind vane. Direction transmitter is modified to provide direction-dependant DC output.

(3) Dry Bulb Temperature/Wet Bulb Temperature

Linearized Yellow Spring Model 44202 Thermistors with a self-wetting wet bulb. Aspiration is provided by a vertical axis fan at not less than 2.5 meters/second and is not significantly influenced by ambient winds. A standard National Weather Service Stevenson screen houses the entire system and provides solar radiation shielding.

(4) Station Pressure

Texas Electronics Aneroid/LVDT Unit (Linear Variable Differential Transformer): a precision aneroid cell having electrical but no direct mechanical connection to the motion-sensing transducer (a virtually frictionless coupling).

(5) Rainfall

A Belfort Model 5-780 weighing-bucket raingage in which the spring and balance mechanism is replaced by a weight-sensing load cell.

(6) Corona Probe

Selected SAM sites were instrumented with probes for determining the corona current that flows beneath storms.

Resolutions were determined by the site data logger's analog-to-digital converter, as follows:

Parameter	Range	Meteorological Resolution (Not accuracy)
Pressure as P_{AVG}, P_{MIN}*	850-1000 mb	0.6 mb
Rainfall	0-230 mm	1 mm
Winds as U, V	0- ± 56 m/s	0.4 m/s
Winds as speed max*	0 - 56 m/s	0.4 m/s
Temperature as T_d, T_w	0 - 50° C	0.2° C
Corona Current	0 - ± 1.25 μA	0.1 μA

* Additionally, the maximum value of the wind speed sensor for each minute and the minimum value of the pressure sensor for each minute are recorded.

The data collection/logging specifications were as follows:

(1) Number of analog channels; 16

(2) Analog sample and hold aperture; ≃4 μs

(3) A/D conversion

Quantization; 8 bits
Speed; ≃ 100 μs

(4) Sampling rate; 1 sample per parameter per second

(5) Signal averaging; 60 1-s samples forming 1-minute means

(6) Data storage medium; magnetic cassette tape CNRZ format, 600 bpi density.

NATIONAL SEVERE STORMS LABORATORY

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

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. Brent B. Goddard. 34 p. (PB-168208)

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

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

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

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

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 Report of the Kinematic Properties of Certain Small-Scale Systems. Dansey 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)

No. 16 Analysis of Selected Aircraft Data from NSSP Operations, 1962. Tetsuya Fujita. May 1963. 29 p. (PB-168221)

No. 17 Analysis Methods for Small-Scale Surface Network Data. Dansey T. Williams. August 1963. 20 p. (PB-168222)

No. 18 The Thunderstorm Wake of May 4, 1961. Dansey T. Williams. August 1963. 233 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. NSSL Staff. 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 Studies 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 Probing Balloon Motion by Doppler Radar. Robert 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)

No. 40 Objective Detection and Correction of Errors in Radiosonde Data. Rex L. Inman. June 1968. 50 p. (PB-180284)

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 Comparative Study. K. E. Wilk, J. 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)

No. 53 Rawinsonde Observation and Processing Techniques at the National Severe Storms Laboratory. Stanley L. Barnes, James H. Henderson and Robert J. Ketchum. April 1971. 245 p. (COM-71-00707)

NO. 54 Model of Precipitation and Vertical Air Currents. Edwin Kessler and William C. Bumgarner. June 1971. 93 p. (COM-71-00911)

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

No. 56 Pilot Chaff Project at NSSL. Edward A. Jessup. November 1971. 36 p. (COM-72-10106)

No. 57 Numerical Simulation of Convective Vortices. Robert P. Davies-Jones and Glenn T. Vickers. November 1971. 27 p. (COM-72-10269)

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 Doppler Radar Velocity Fields. G. B. Walker and L. D. Hennington. 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)

No. 63 Observations of Severe Storms on 26 and 28 April 1971. Charles L. Vlcek. April 1973. 19 p. (COM-73-11200)

No. 64 Meteorological Radar Signal Intensity Estimation. Dale Sirmans and R. J. Doviak. September 1973. 80 p. (COM-73-11923/2AS)

No. 65 Radiosonde Altitude Measurement Using Double Radiotheodolite Techniques. Stephan P. Nelson. September 1973. 20 p. (COM-73-11932/9AS)

No. 66 The Motion and Morphology of the Dryline. Joseph T. Schaefer. September 1973. 81 p. (COM-74-10043)

No. 67 Radar Rainfall Pattern Optimizing Technique. Edward A. Brandes. March 1974. 16 p. (COM-74-10906/AS)

No. 68 The NSSL/WKY-TV Tower Data Collection Program: April-July 1972. R. Craig Goff and W. David Zittel. May 1974. 45 p. (COM-74-11334/AS)

No. 69 Papers on Oklahoma Thunderstorms, April 29-30, 1970. Stanley L. Barnes, Editor. May 1974. 147 p. (COM-74-11474/AS)

No. 70 Life Cycle of Florida Keys' Waterspouts. Joseph H. Golden. June 1974. 147 p. (COM-74-11477/AS)

No. 71 Interaction of Two Convective Scales Within a Severe Thunderstorm: A Case Study. and Thunderstorm Wake Vortex Structure and Aerodynamic Origin. Leslie R. Lemon. June 1974. 43 p. (COM-74-11642/AS)

NO. 72 Updraft Properties Deduced from Rawinsoundings. Robert P. Davies-Jones and James H. Henderson. October 1974. 117 p. (COM-75-10583/AS)

No. 73 Severe Rainstorm at Enid, Oklahoma - October 10, 1973. L. P. Merritt, K. E. Wilk, and M. L. Weible. November 1974. 50 p. (COM-75-10583/AS)

No. 74 Mesonetwork Array: Its Effect on Thunderstorm Flow Resolution. Stanley L. Barnes. October 1974. 16 p. (COM-75-10248/AS)

No. 75 Thunderstorm-Outflow Kinematics and Dynamics. R. Craig Goff. December 1975. 63 p. (PB-250808/AS)

No. 76 An Analysis of Weather Spectra Variance in a Tornadic Storm. Philippe Waldteufel. May 1976. 80 p. (PB-258456/AS)

No. 77 Normalized Indices of Destruction and Deaths by Tornadoes. Edwin Kessler and J. T. Lee. June 1976. 47 p. (PB-260923/AS)

No. 78 Objectives and Accomplishments of the NSSL 1975 Spring Program. K. Wilk, K. Gray, C. Clark, D. Sirmans, J. Dooley, J. Carter, and W. Bumgarner. July 1976. 47 p. (PB-263813/AS)

No. 79 Subsynoptic Scale Dynamics As Revealed By The Use of Filtered Surface Data. Charles A. Doswell III. December 1976. 40 p. (PB-265433/AS)

No. 80 The Union City, Oklahoma Tornado of 24 May 1973. Rodger A. Brown, Editor. December 1976. 235 p. (PB-269443/AS)

No. 81 Mesocyclone Evolution and Tornado Generation Within the Harrah, Oklahoma Storm. Edward A. Brandes. May 1977. 28 p. (PB-271675/AS)

No. 82 The Tornado: An Engineering-Oriented Perspective. Joseph E. Minor, James R. McDonald, and Kishor C. Mehta. December 1977. 196 p. (PB-281860/AS)

No. 83 Spring Program '76. R. Alberty, J. Weaver, D. Sirmans, J. Dooley, and B. Bumgarner. December 1977. 130 p. (PB-280745/AS)

No. 84 Spring Program '77. Peter S. Ray, John Weaver, and NSSL Staff. December 1977. 173 p. (PB-284953/AS)

No. 85 A Dual-Doppler Variational Objective Analysis as Applied to Studies of Convective Storms. Conrad L. Ziegler. November 1978. 116 p. (PB-293581/AS)

No. 86 Final Report on the Joint Doppler Operational Project (JDOP) 1976-78. Prepared by Staff of the National Severe Storms Laboratory, Environmental Research Laboratories; Weather Radar Branch, Air Force Geophysics Laboratory; Equipment Development Laboratory, National Weather Service; and Air Weather Service, United States Air Force. March 1979. 84 p. (PB80-107188/AS)

No. 87 An Analysis of the Clear Air Planetary Boundary Layer Wind Synthesized from NSSL's Dual Doppler-Radar Data. Myron I. Berger and R. J. Doviak. June 1979. 55 p. (PB-300865/AS)

No. 88 The Relationship of the 300-mb Jet Stream to Tornado Occurrence. Carolyn M. Kloth and Robert P. Davies-Jones. July 1980. 62 p. (PB81-118960)

No. 89 A Study of Hail Production in a Supercell Storm Using a Doppler Derived Wind Field and a Numerical Hail Growth Model. Stephan P. Nelson. December 1980. 90 p. (PB81-17822Q)

No. 90 Summary of AEC-ERDA-NRC Supported Research at NSSL 1973-1979. J. T. Lee, Editor. March 1981. 93 p. (PB81-220162)

No. 91 1980 Spring Program Summary. R. J. Doviak, Editor. April 1981. 128 p. (PB81-234940)

No. 92 Multiple Doppler Radar Analysis of Severe Thunderstorms: Designing a General Analysis System. R. A. Brown, C. R. Safford, S. P. Nelson, D. W. Burgess, W. C. Bumgarner, M. L. Weible, and L. C. Fortner. June 1981. 18 p. (PB82-114117)

No. 93 1981 Spring Program Summary. William L. Taylor, Editor. March 1982. 97 p. (PB82-244757)

No. 94 Multiple Doppler Radar Derived Vertical Velocities in Thunderstorms: Part I - Error Analysis and Solution Techniques, Part II - Maximizing Areal Extent of Vertical Velocities. Stephan P. Nelson and Rodger A. Brown. October 1982. 21 p. (PB83-152-553)

No. 95 Single Doppler Velocity Signatures: An Atlas of Patterns in Clear Air/Widespread Precipitation and Convective Storms. Vincent T. Wood and Rodger A. Brown. November 1983. 71 p.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1984-0-776-001/4111