NOAA Technical Memorandum ERL NSSL-100

1986 SPRING PROGRAM SUMMARY

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Norman, Oklahoma
February 1987

UNITED STATES DEPARTMENT OF COMMERCE

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1986 Spring Program Summary

1. INTRODUCTION

The National Severe Storms Laboratory (NSSL) conducts scientific research, technology development programs and operational implementation activities designed to improve understanding and predictions of middle latitude severe weather phenomena, and to improve remote sensors for research support and operational detection and warning of all types of severe weather. To help meet these objectives, NSSL conducted the 1986 Spring Program to supply a data base for the study of severe weather. This report presents a summary of the data collected from 1 April 1986 to 10 June 1986. It is intended to serve as a guide to data taken and as a mechanism to refine data requests. 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.

Principal objectives of the 1986 Spring Program were to (1) enhance the data base of the Storm Electricity Group engaged in determining lightning effects on precipitation, lightning characteristics and the relationships between the various storm electrical phenomena and the observable storm parameters, (2) obtain a dual Doppler data set from a tornadic storm, (3) acquire single Doppler data from several squall lines, along with radiosonde data prior to squall line passage, (4) transfer real-time Doppler data to Oklahoma City NWSFO to aid in severe weather detection and warnings, and familiarize the NWS forecasters with interpreting the Doppler displays, (5) collect Doppler data on microbursts to determine precursors of the phenomenon as well as the asymmetry of the low altitude outflow.

The 1986 program was principally an in-house effort; however, The University of Oklahoma participated in two interesting data collection projects. One project launched radiosondes in various locations with respect to a severe thunderstorm, and along and ahead of the dryline on both active and non-active days. The other project placed instrumented packages underneath a severe thunderstorm to obtain distributions of pressure and temperature associated with mesocyclones and gust fronts.

A substantial amount of data was collected during the 1986 Spring Program. Section 2 describes the experiments and their objectives, while Section 3 describes the various instruments used to observe the weather. Weather summaries of all the storm days are found in Section 4 along with bar graphs showing the data that were collected. Out of the 71 days during which the Spring Program was in operation, data important to the objectives outlined in Section 2 were collected on 26 days.

Occurring during spring 1986 but not listed as a Section 2 experiment was a PROFS workstation demonstration at NSSL. With assistance from PROFS personnel, a workstation was positioned in the NSSL Forecast Room from 15 April until Spring Program end. A separate report on the demonstration is being prepared and will appear under separate cover. Black and white prints of color workstation images are used to document conditions for the most significant storm days.

2. EXPERIMENTS: PRINCIPAL INVESTIGATORS AND OBJECTIVES

The experiments have been categorized into three main areas of interest to more clearly emphasize the broad range of scientific objectives that were addressed in the 1986 Spring Program. These three areas are: clear air and early convection, convective storms (non-severe) and convective storms (severe).

2.1 Clear Air and Early Convection

2.1.1 Clear Air Echoes as Observed by Doppler Radar (Sirmans, Dooley)

Objectives:

a. Determine the type (birds, insects, etc.) of targets that are being observed.

b. Examine the signal strength of clear air targets for purposes of optimizing the radars polarization.

2.1.2 Real Time Wind Analysis in the Pre-Convective Environment (Rabin, Doviak, Smith, Zrnic')

Objectives:

Routinely measure the kinematic properties of the wind for application to thunderstorm forecasting. The primary aim is to implement and test the following items in "near real time" (approximately 30 minutes from data collection):

a. Preprocessing (velocity dealiasing, editing, smoothing) of clear air radar data.

b. Techniques for mesoscale mapping of the wind fields using single Doppler radar data.

c. Model for diagnosis of changes in airmass stability, which uses an initial sounding and subsequent radar wind data as input.

2.1.3 50 MHz Profiler (Kessler, Doviak, Thomas)

Objectives:

a. Monitor the pre-storm environment.

b. Compare profiler data with both rawinsonde and Doppler data.

2.1.4 403 MHz Profiler Detection Prediction (Kessler, Sirmans)

Objective:

Compare measured values of the refractive index structure constant using data from the 403 MHz profiler and from the Norman Doppler radar when vertically pointed.

2.1.5 DOPLOON-Balloon-Aided Wind Finding by Doppler Radar (Sirmans, Zrnic', Forsyth)

Objective:

Acquire and track automatically a balloon with a pulsed Doppler weather radar, so that wind speed and direction can be determined. The suitability of this technique for routine wind profiling with a NEXRAD type radar is to be examined through an error analysis and comparisons with rawinsondes.

2.1.6 Water Resource Board Plume Detection (Sirmans)

Objective:

Evaluate the minimum existing signal detection capability of the Cimarron radar dual polarization system and the Norman radar fixed polarization system. These data are also to be used for the development of lower signal processing techniques.

2.2 Convective Storms - Non-Severe

2.2.1 Lightning Effects on Precipitation (Mazur, Zrnic')

Objective:

Determine the short and long term effects of lightning on hydrometeors. Such things as growth and breakup of drops, reorientation of crystals, rain gush, and changes in velocity and size distribution are to be investigated.

2.2.2 Lightning Mapping and Storm Evolution (Rust, MacGorman)

Objectives:

1. Locate the source of lightning discharge processes in space (x,y,z) and time in non-severe storms.

2. Determine lightning initiation regions and the storm structure and dynamics that accompany these regions.

3. Measure progression speeds for different lightning processes.

4. Determine storm characteristics that influence production of intracloud flashes and of lightning lowering negative and positive charge to ground.

5. Determine relationships among coevolving fields of precipitation, wind, turbulence, and lightning.

6. Determine lightning characteristics during the genesis, maturity and dissipation of storms.

7. Measure lightning parameter characteristics indicative of non-severe storms.

8. Track lightning activity, identify electrically active storms and provide ground truth for other experiments.

2.2.3 DOOM-Detection of Oklahoma Microbursts (Eilts, Doviak, Witt)

Objective:

Collect single, and especially dual-Doppler, radar data on microbursts to determine precursors of this phenomenon as well as the asymmetry of the low altitude flow.

2.2.4 Characteristics of Hydrometeors (Zrnic')

Objective:

The phase and size of hydrometeors can be determined to some extent from polarization measurements. Whereas differential reflectivity combined with the reflectivity factor can be used to identify hail, this study is to explore the possibility of gauging hail size from the differential propagation phase shift. Also, rain rate estimates from polarization measurements are to be compared to measurements by a disdrometer.

2.3 Convective Storms-Severe

2.3.1 DOPLIGHT (Forsyth, Burgess, Lee)

Objective:

The DOPLIGHT project started in 1984 to support the warning operations at the NWS Forecast Office (WSFO) at Oklahoma City by making available displays of reflectivity and velocity from the Norman Doppler radar in near real-time. During 1986 the project is to be overhauled to include NEXRAD-like displays of base products. The lightning data is also to be added for the very first time along with an improved interactive capability so that NWS forecasters can control their displays from Oklahoma City instead of having to send a meteorologist to Norman.

2.3.2 DOOM-Detection of Oklahoma Microbursts (Eilts, Doviak, Witt)

Objective:

Collect single, and especially dual-Doppler, radar data on microbursts within severe storms to determine precursors of this phenomenon as well as the asymmetry of the low altitude flow.

2.3.3 Squall Line Dynamics (Hane)

Objective:

Relate the overall structure of well-organized squall lines to the environments in which they exist by examining a collection of cases.

2.3.4 Tornado Intercept-Rawinsonde (Bluestein)

Objectives:

Obtain soundings:

1) along and head of the dryline on both active and non-active days.

2) in various locations with respect to severe thunderstorms.

3) adjacent to wall clouds.

4) in outflow regions.

2.3.5 Tornado Intercept and Lightning (Davies-Jones, Rust)

Objectives:

1. Visual, photographic, and video documentation of storm features and tornadoes.

2. Surface meteorological observations in storm environment.

3. Deployment of TOTO in path of tornado and beneath mesocyclones.

4. Measurements of electric field, electric field changes associated with lightning, lightning optical transients, corona beneath storms.

5. Provide data and support collaborative experiments (OU intercept).

2.3.6 Field Measurements of Surface Pressure under Severe Storms (Lesins)

Objective:

Obtain the surface pressure and temperature distributions associated with mesocyclones and gust fronts and perhaps also obtain pressure measurements within a tornado.

2.3.7 Tornadic Storm Evolution (Brandes)

Objective:

Determine the origin of air and the vorticity budget for air parcels within tornadic mesocyclones.

2.3.8 Storm Morphology and Interaction Between Storm Scale and Mesoscale (Brown, Burgess)

Objectives:

1. Study kinematic and dynamic processes within severe storms.
2. Examine the interactions between these storms and their environments.

2.3.9 Lightning Effects on Precipitation (Mazur, Zrnic')

Objective:

Determine the short and long term effects of lightning on hydrometeors. Such things as growth and breakup of drops, reorientation of crystals, rain gush, and changes in velocity and size distribution are to be investigated.

2.3.10 Lightning Mapping and Storm Evolution (Rust, MacGorman)

Objectives:

1. Locate the source of lightning discharge processes in space (x,y,z) and time in severe storms.
2. Determine lightning initiation regions and the storm structure and dynamics that accompany these regions.
3. Measure progression speeds for different lightning processes.
4. Determine storm characteristics that influence production of intracloud flashes and of lightning lowering negative and positive charge to ground.
5. Determine relationships among coevolving fields of precipitation, wind, turbulence, and lightning.
6. Determine lightning characteristics during the genesis, maturity and dissipation of storms.
7. Measure lightning parameter characteristics indicative of tornadic and severe (nontornadic) storms.
8. Track lightning activity, identify electrically active storms and provide ground truth for other experiments.

2.3.11 Lightning Strike Detection Systems Evaluation (MacGorman)

Objective:

Evaluate performance of magnetic-direction-finder and time-of-arrival systems for locating lightning strikes to ground.

2.3.12 Lightning Ground Strike and Storm Evolution (MacGorman)

Objectives:

1. Provide ground strike locations in real time for storms within a 345 km range.

2. Examine the evolution of ground strike characteristics during the lifecycle of storms.

3. Determine influence of storm parameters on cloud-to-ground flashing rates, strokes per flash, ground strike point density, polarity, location, and amplitude.

4. Tabulate ground strike characteristics continuously for lightning climatology.

5. Examine correspondence between ground strike location and other lightning parameters.

2.3.13 Characterization of Hydrometeors (Zrnic')

Objective:

The phase and size of hydrometeors can be determined to some extent from polarization measurements. Whereas differential reflectivity combined with the reflectivity factor can be used to identify hail, this study is to explore the possibility of gauging hail size from the differential propagation phase shift. Also, rain rate estimates from polarization measurements are to be compared to measurements by a disdrometer.

3. INSTRUMENTATION

This section briefly describes the equipment and facilities (Figs. 1 and 2) employed in data acquisition during the 1986 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.

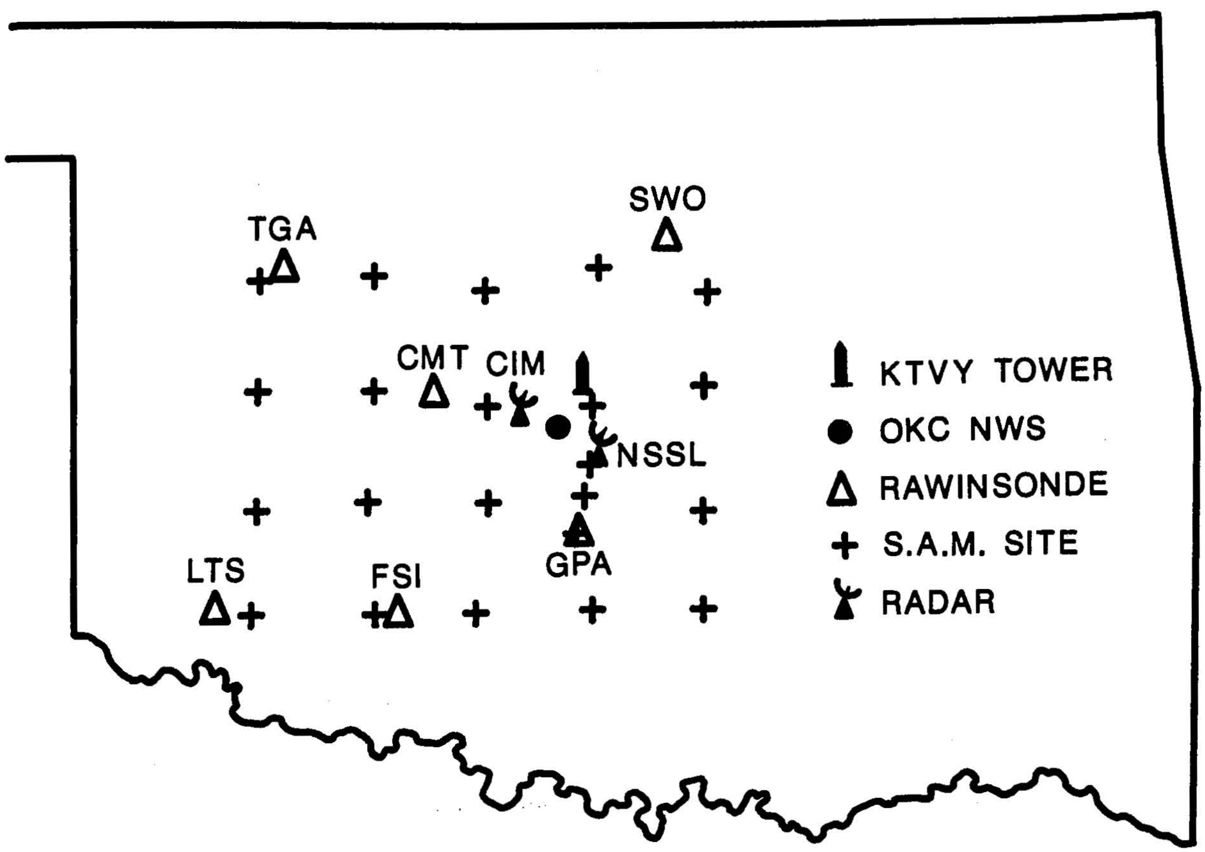


Figure 1.--1986 Facilities.

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 (see Fig. 1). Each radar records one or more of the first three moment estimates (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 have 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 13 April 1986 to 24 May 1986 for most storm days.

3.3 Stationary Automated Mesonetwork

A 22-station network located in central and west-central Oklahoma with an average station spacing of approximately 50 km (see Fig. 1) was operated in support of NSSL research. Surface data were archived during the period from 1 April 1986 to 1 June 1986. These data were recorded as one minute mean values of wind speed, wind direction, dry bulb temperature, wet bulb temperature, station pressure, and rainfall amount. In addition, the maximum value of the wind speed and the minimum value of the pressure during each minute were recorded. Detailed characteristics of the NSSL Stationary Automated Mesonetwork are given in Appendix C, along with a summary of the daily data collection.

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. It is instrumented at seven levels: 7, 26, 45, 89, 177, 266 and 441 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, total rainfall, and total solar radiation. Data were recorded continuously during the 1986 Spring Program at a 10-second sample interval.

3.5 Rawinsonde

The 1986 rawinsonde network was comprised of six units in central and western Oklahoma (see Fig. 1). Units at Altus (LTS), Taloga (TGA), Criner (GPA) and Calumet (CMT) were operated by personnel from the U.S. Air Force Sixth Weather Squadron Mobile. The U.S. Army Field Artillery Board operated the unit at Stillwater (SWO), while the 75th Field Artillery Brigade and the 212th Brigade at Fort Sill (FSI) supported sounding requests for some days.

3.6 Very High Frequency (VHF) Lightning Mapping System

A wide-band VHF system, employing time-difference-of arrival techniques, provided azimuth information for lightning occurring within a nominal 60-km range over the entire hemisphere above the horizon. Maximum instantaneous rate of reception was usually 16,000 per second. Maximum peak rates could be manually switched to 64,000 per second. In both cases, the maximum continuous rate of reception was approximately 12,000 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.

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, video tape and strip chart, with time code synchronized to WWV. The SEB usually operated in one of two modes. In the local mode, data were collected from all sensors, and analog data were usually recorded at a tape speed of 60 ips. In the distant mode, the primary sensor recorded was the extremely low frequency electric field sensor, and the recording speed was lower.

3.8 Lightning Strike Locator

The cloud-to-ground (CG) lightning location system provided time, location, peak field strengths, and number of component strikes for CG flashes in northern Texas, Oklahoma, Kansas, and eastern Nebraska. The system consisted of seven direction finder (DF) stations (see Fig. 2) 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), Watonga (DF4), Salina (DF5), Smith Center (DF6), and Marysville (DF7). All stations 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 recorded data on digital magnetic tape, hard copy printer, and plotter.

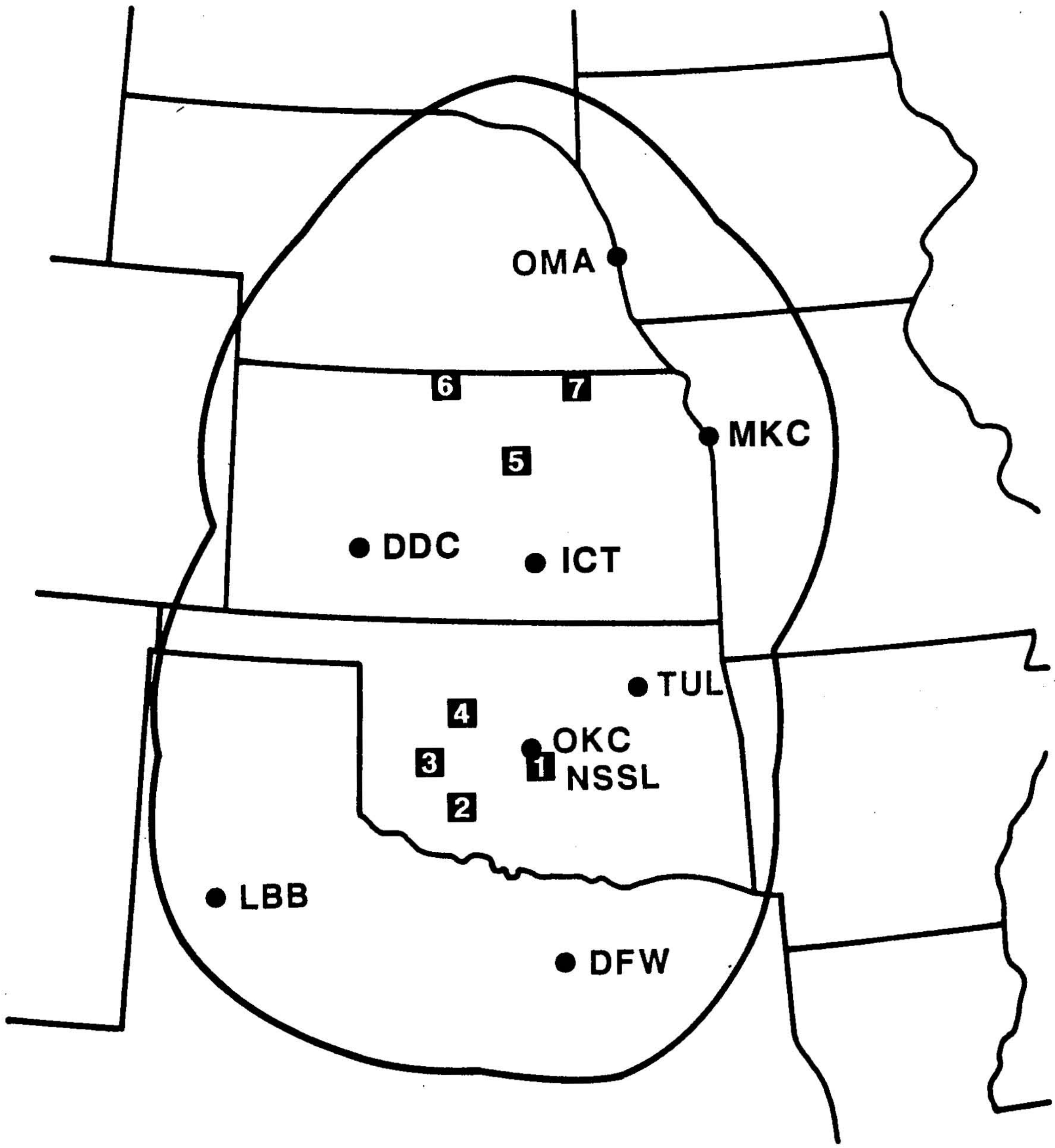


Figure 2.--Locations of the seven direction finder (DF) stations in the lightning strike locator system. The areal coverage of the system is denoted by the solid line.

3.9 NSSL Mobile Laboratories

The primary intercept vehicle for storm intercept, NSSL1, was replaced this season by instrumenting a new van (15-passenger size) with a 4 kW 110 V ac generator, electric field sensors, optical detectors, two remotely controlled pan-tilt units with azimuth position readouts for the TV cameras atop the lab, a 14 channel wide-bandwidth analog tape recorder, a LORAN-C navigation receiver for position location, and provisions for meteorological sensors and balloon telemetry receiving equipment. Hand-held sensors of temperature, dew point, atmospheric pressure, and wind speed were again also carried. A new and innovative instrument was installed atop the mobile lab and coaxially aligned with the color TV camera to measure the speed of propagation of lightning channels between the ground and the cloud by using eight silicon detectors behind horizontal slits in the focal plane of a lens on a camera body. The TV records channel geometry, and subsequently two-dimensional velocity, for the first time while mobile.

The other part of the Intercept Project consisted of two vehicles, NSSL2 (a van) and a pickup truck that traveled together. The pickup truck carried TOTO (TOtable Tornado Observatory), a hardened instrument package that records pressure, windspeed, wind direction and dry-bulb temperature. The goal was to deploy TOTO ahead of tornadoes, mesocyclones, and gust fronts to obtain continuous measurements of surface variables.

Photographic and verbal documentation of thunderstorm features were obtained using cameras (video, movie and still), and portable tape recorders. Pscychrometers were used to measure dry- and wet-bulb temperatures near severe thunderstorms.

All vehicles were equipped with FM radios, and NSSL1 and 2 also had radio telephones. FM communications with the Nowcaster at NSSL were routed through a repeater located at the 440 m level on the 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 crews to exchange information with each other.

NSSL provided support to Dr. Howard Bluestein for the release of rawinsondes near, and into, severe thunderstorms (see 2.3.4), and to Dr. Glen Lesins for the deployment of portable instrument packages in the path of a severe thunderstorm (see 2.3.6). These units were also equipped with FM radios.

4. OPERATIONAL PERIODS AND DAILY WEATHER SUMMARIES

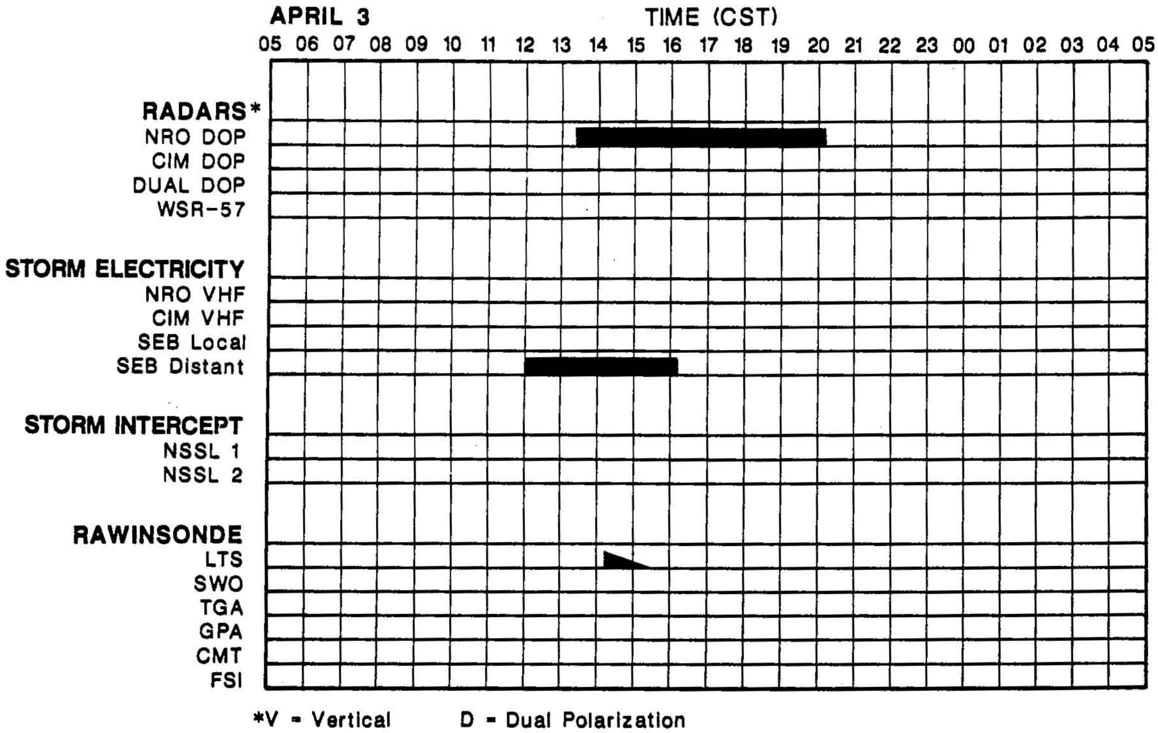
This section provides a weather and data collection summary for each storm day. Also included for comparison are a few days when storms did not occur, but the potential for severe weather was perceived by the NSSL forecasting team. Data were collected on a total of forty days during the spring, and twenty-six of those days are listed here. The data collection on the remaining days was usually limited to one or two soundings, and these data are listed in Appendix A.

The summaries are listed chronologically beginning on 3 April 1986 and ending on 10 June 1986. The Stationary Automated Mesonetwork (SAM) and KTVY Meteorological Tower data are not included, since the observations are nearly continuous on most days. For a particular day of interest, one can refer to Appendix C to determine the availability and quality of the SAM data.

The data collection is presented using bar graphs with the following abbreviations:

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 (Section3.6)
SEB Local	=	Storm Electricity Building with additional sensors recorded, usually at 60 ips (Section 3.7)
SEB Distant	=	Storm Electricity Building analog recording speed lower and fewer sensors recorded (Section 3.7)
NSSL1	=	Storm Electricity Mobile Laboratory (Section 3.9)
NSSL2	=	Mobile Intercept Vehicles (Section 3.9)
LTS	=	Altus rawinsonde launch site (Section 3.5)
SWO	=	Stillwater rawinsonde launch site (Section 3.5)
TGA	=	Taloga rawinsonde launch site (Section 3.5)
GPA	=	Criner rawinsonde launch site (Section 3.5)
CMT	=	Calumet rawinsonde launch site (Section 3.5)
FSI	=	Fort Sill rawinsonde launch site (Section 3.5)
V	=	Doppler radar in vertically pointing mode (Section 3.1)
D	=	Doppler radar in dual polarization mode (Section 3.1)

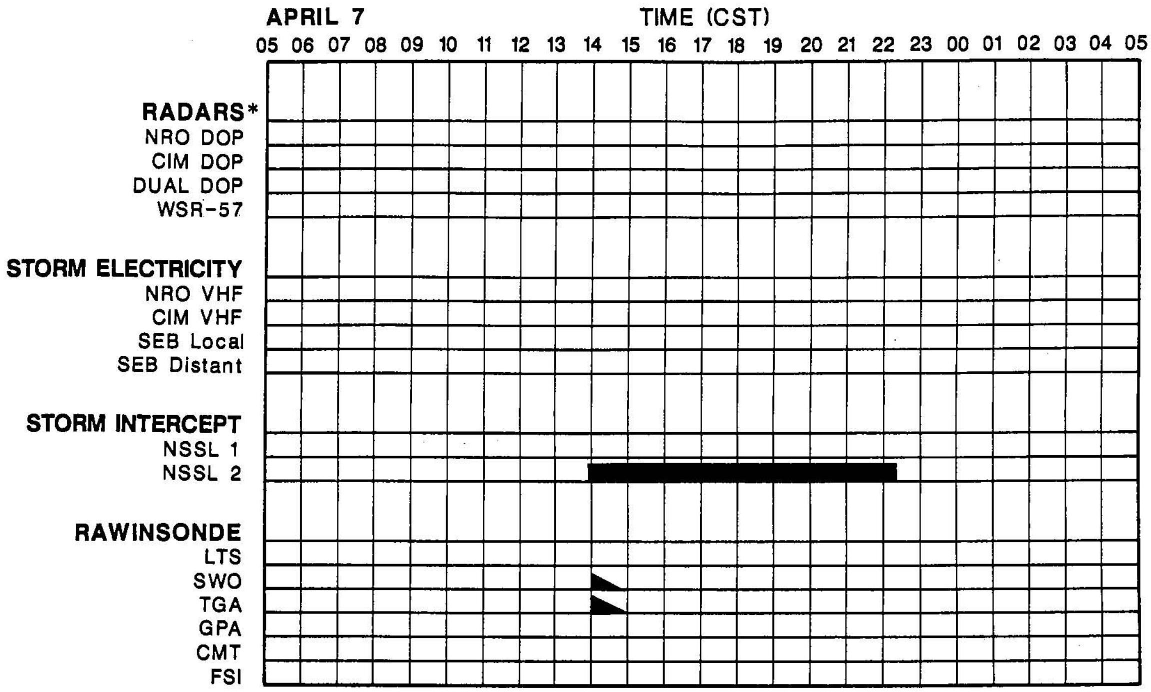
4.1 3 April - Julian day 93



4.1 Weather Summary

A vertically stacked low-pressure system was in southeastern Colorado and a short wave trough was swinging around the upper low, moving over Texas and Oklahoma during the afternoon. A dryline extended in a north-south direction from Russell, Kansas to Fort Sill, Oklahoma and continued south into Texas. The atmosphere to the east of the dryline was relatively unstable with lifted indices near -5°C determined from the Fort Sill and Oklahoma City soundings. Surface dewpoints were above 60° F from Texas into eastern Oklahoma. However, temperatures only reached the 70° F range throughout the southern plains, and so the risk of severe weather was somewhat lessened. Nonetheless, by 1200 CST convection fired along the dryline over north central Texas and began to spread northward. As the storms moved slowly eastward, considerable hail fell across Oklahoma and damaging winds were reported along the Red River. Norman Doppler and Storm Electricity data were collected.

4.2 7 April - Julian day 97



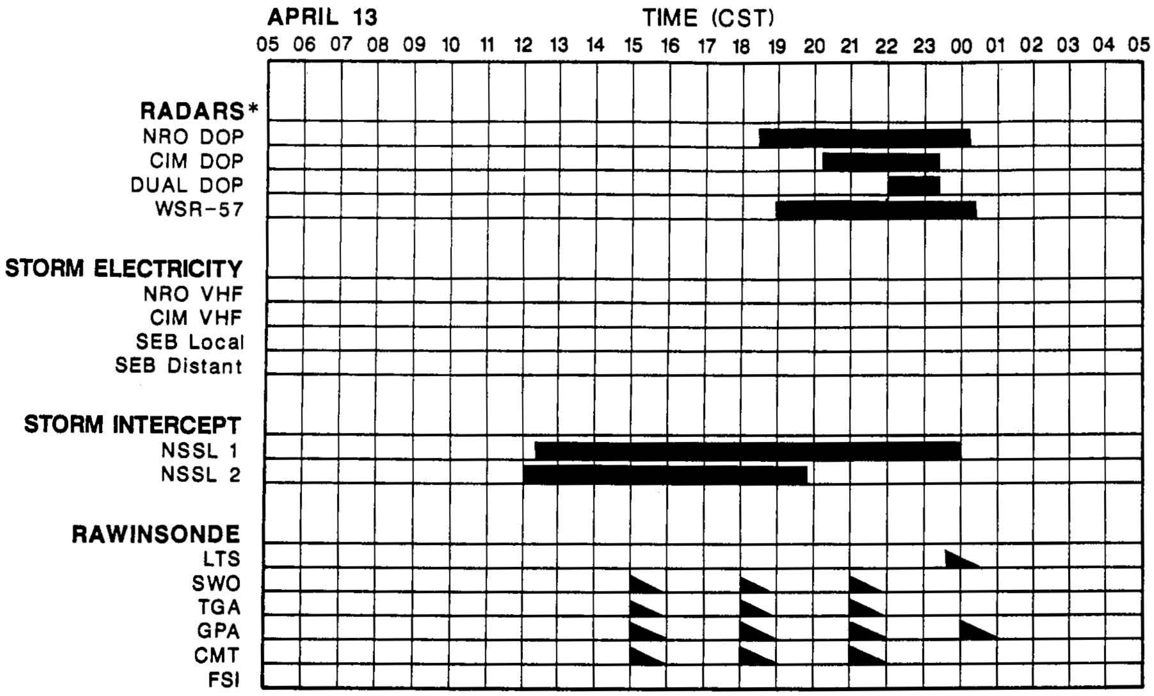
*V = Vertical D = Dual Polarization

<u>4.2 Weather Summary</u>

A stationary frontal system lay across Kansas from west to east with a weak low-pressure area between Dodge City and Russell, Kansas. During the morning a dryline developed southward from the low along the Texas Panhandle-western Oklahoma border to near Childress, Texas. Aloft, a ridge dominated the southern plains with an anticyclonically curved jet stream from southwest Colorado to northern Nebraska to southern Illinois. Convection which had developed over the northern high plains the previous evening was weakening over eastern Kansas and Missouri with a nearly stationary outflow boundary from west of Emporia, Kansas, across northeast Oklahoma to beyond Fayetteville, Arkansas.

During the afternoon, heating and low-level moisture advection produced an extremely unstable airmass across Oklahoma and southern Kansas (LI's of -8 to -10). Severe thunderstorms developed along the front and outflow boundary in eastern Kansas and northeast Oklahoma, perhaps aided by a southeastward moving upper-air impulse along and south of the jet stream. Less moisture and a capping inversion were present further west along the front and dryline, inhibiting deep convection in western Kansas and Oklahoma. The eastern storms produced much severe weather, including 9 tornadoes in southeast Kansas, 4 in extreme southwest Missouri and 1 in northeast Oklahoma. Hail diameters in the storm area were reported to have exceeded 4 inches. An NSSL intercept team viewed the storms from some distance but were too far away for interception. Radar data were not collected due to the long range.

4.3 13 April - Julian day 103

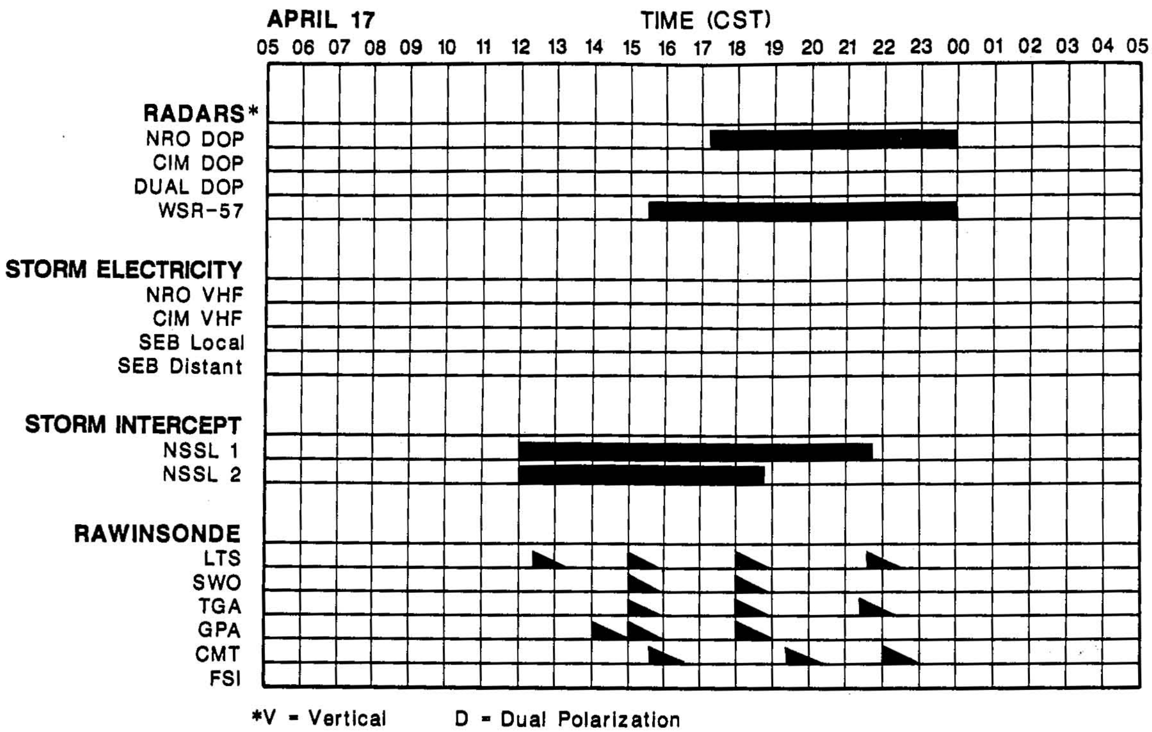


*V = Vertical D = Dual Polarization

4.3 Weather Summary

A low pressure system was located in southwestern Nebraska and a dryline extended southward from the low center across western Kansas and extreme western Oklahoma. A long-wave trough was situated over the western United States and a strong short wave was being ejected northward into the central plains. This short wave moved over Nebraska and into Iowa by late afternoon with the southern edge of the shortwave moving over Oklahoma. The upper-level dynamics favored convective activity in Nebraska and Kansas, but not in Oklahoma. However, an unstable atmosphere with surface dewpoints above 60° F in Oklahoma caused convection to propagate southward into Oklahoma by early evening. At 1800 CST, a squall line had developed and extended from central Nebraska into southern Kansas. By 2300 CST the squall line extended into northeastern Oklahoma. Tornadoes were reported from South Dakota to Oklahoma, with one striking the Tulsa suburb of Broken Arrow. Other severe weather occurred over northern and eastern Oklahoma. Data were collected from all NSSL sensors during the system's passage but the strongest storms generally stayed north and east of the NSSL network.

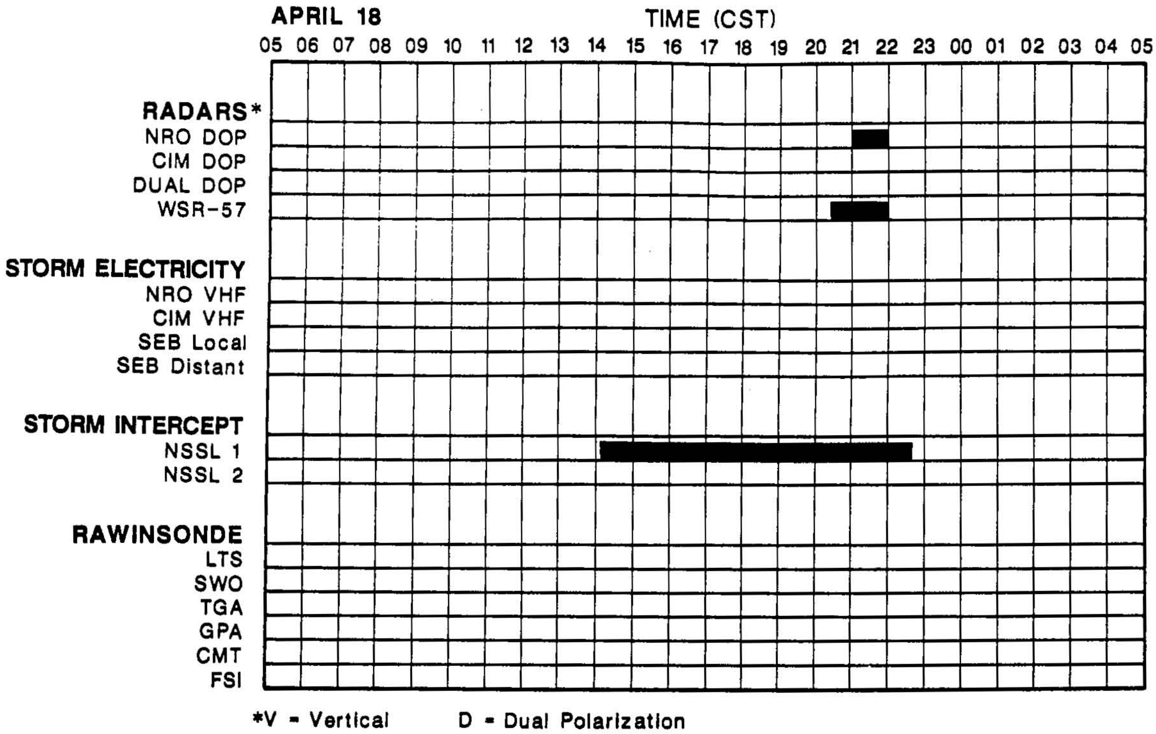
4.4 17 April - Julian day 107



4.4 Weather Summary

The morning began with a cold front extending southward into eastern New Mexico from a low centered in Colorado. An upper-level trough was over the western U.S., but it was starting to weaken. As the day progressed, the surface low moved slowly eastward into Nebraska and the cold front pushed into the Texas panhandle. Strong southerly winds ahead of the front brought moist gulf air into central Texas and the western half of Oklahoma. Surface dewpoints were above 55° F and 850 mb dewpoints were above 10°C in a moist tongue that stretched into Oklahoma ahead of the front. At 500 mb, a short wave moved across the central plains late in the day and initiated thunderstorms. By 1500 CST, thunderstorms had already formed in Kansas and were beginning to form along the dryline in Oklahoma. These storms slowly propagated southeastward across parts of Kansas and Oklahoma. Data were collected from the storm intercept groups, rawinsondes, as well as the Norman Doppler and WSR-57 radars. A few reports of hail up to nickel size accompanied the heavier storms.

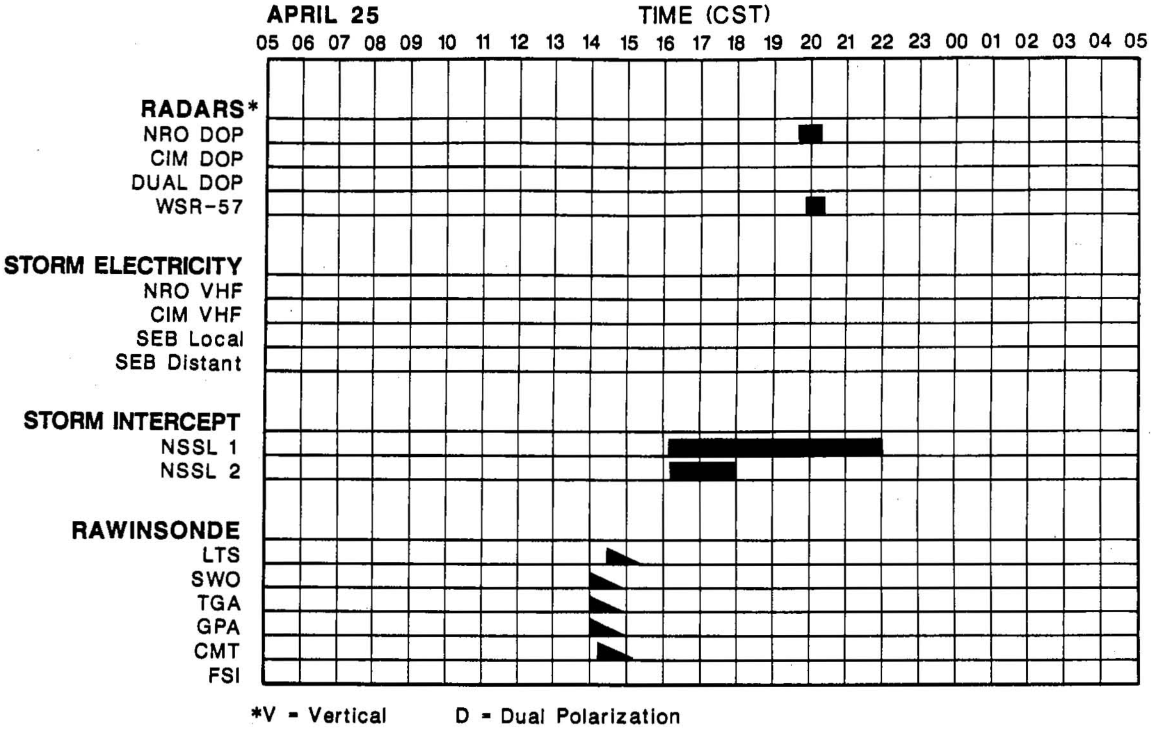
4.5 18 April - Julian day 108



4.5 Weather Summary

The low pressure system that was located in Colorado on the previous day was now centered in southeastern South Dakota with a cold front extending southward across Nebraska, central Kansas, Oklahoma and on into central Texas. The eastern third of Oklahoma was very moist with air from the gulf, while the western sections were occupied by relatively warm and stable dry air from behind the front. The upper level dynamics were very weak over Oklahoma and the lifting of the moist air along the front was the essential triggering mechanism for convection. By 1900 CST, thunderstorms had developed in southwestern Oklahoma and northeastern Texas and hail was reported in both states. Most of the data collected on this day were from the Storm Electricity Intercept group, although the Norman radars did operate for a short period of time when the storms were within range.

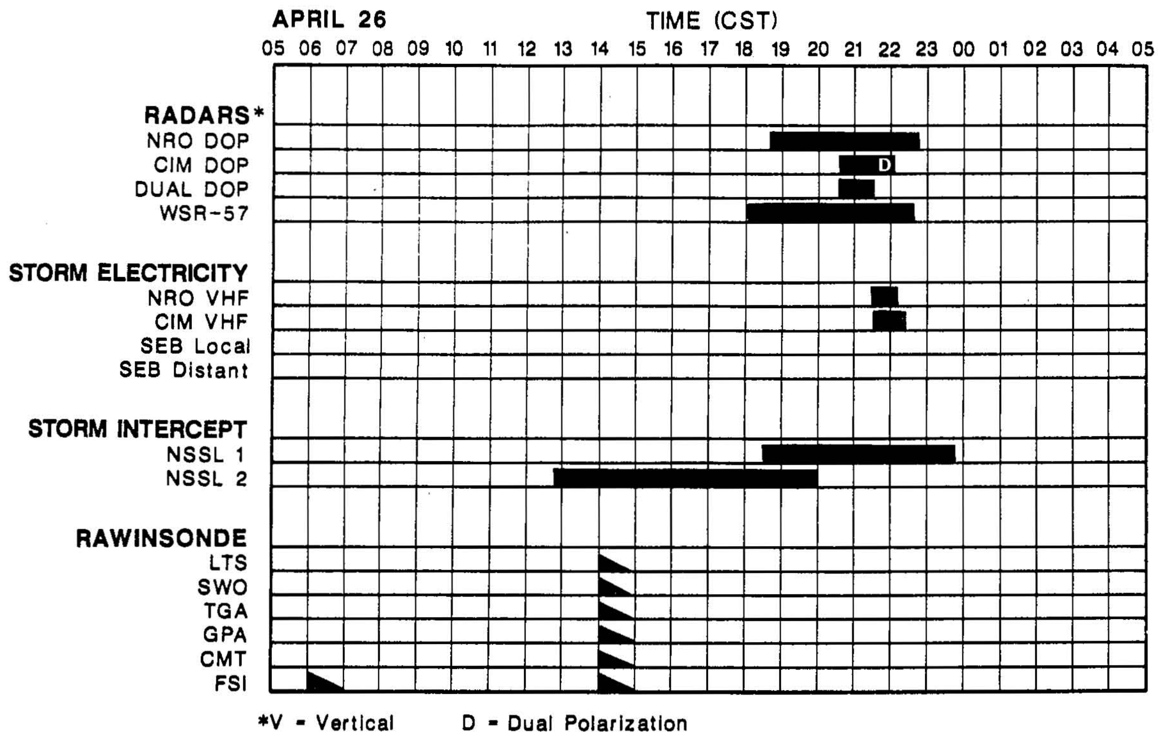
4.6 25 April - Julian day 115



4.6 Weather Summary

An upper-level trough was just beginning to develop over the western U.S., while a surface low was situated in eastern Nebraska. A dryline extended in a north-south direction across central Kansas and western Oklahoma. Surface dewpoints were near 60° F east of the dryline and an 850 mb moist tongue was over Texas, central Oklahoma, and eastern Kansas. A series of short waves were propagating through the upper trough, but the strongest upper-level forcing was further north over the Dakotas. Thus, the forcing over Oklahoma was very weak; however, the weak lifting was sufficient to trigger storms since the moisture influx continued and the dryline persisted. Severe thunderstorms occurred in northwestern Oklahoma along the dryline with strong winds and hail reported. Storm Electricity and Storm Intercept groups collected data, but the radars were only utilized for an hour due to the long range to the storms; rawinsonde data was only collected at 1400 CST.

4.7 26 April - Julian day 116



4.7 Weather Summary

The low that was located in eastern Nebraska on April 25 had pushed into Minnesota and a second low had developed in eastern Colorado in response to the developing long wave trough over the western U.S. The dryline still remained through western Kansas and the Oklahoma and Texas panhandles. Surface dewpoints east of the dryline were increasing and the strong southwesterly flow increased 850 mb dewpoints to above 5° C through much of the region, producing an unstable atmosphere (Fig. 3). An upper jet was located over Nevada on the backside of the upper-level trough and stronger winds were starting to move into the southern plains. Severe thunderstorms developed in the early evening and extended from southern Texas to Minnesota. In Oklahoma, there was a mesolow in the storm formation region along the Red River (Fig. 4), producing numerous reports of strong winds, hail, and tornadoes. Dual and single Doppler radar data were collected, along with WSR-57 data, Norman and Cimarron VHF data, and data from the intercept groups (NSSL1 viewed one tornado in southwest Oklahoma). Rawinsonde data were collected in the pre-convective environment.

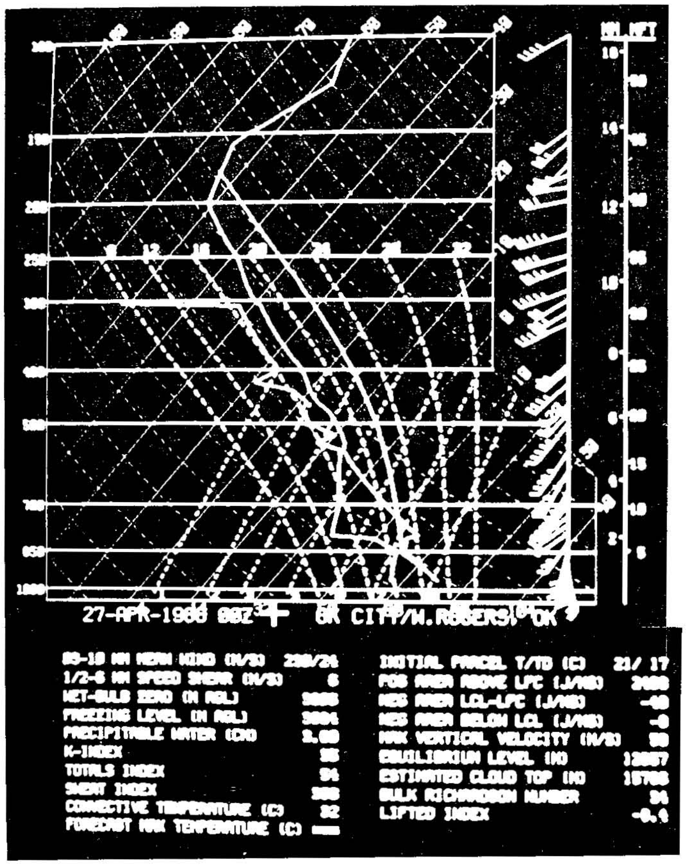


Figure 3.--Oklahoma City sounding for 1800 CST on 26 April (00Z 27 April). Temperature and dewpoint plotted on skew T-log P. Winds (kts) plotted along right edge. Various sounding parameters displayed at bottom. Graphics generated by POWER computer.

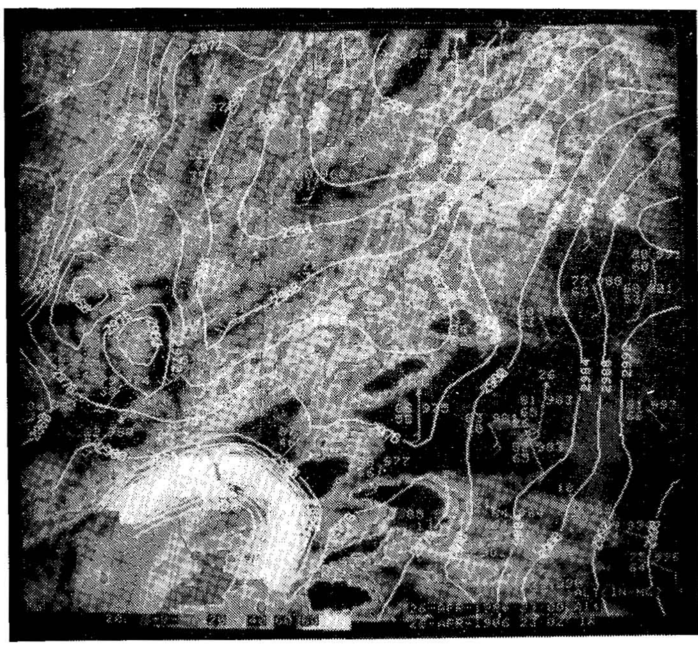
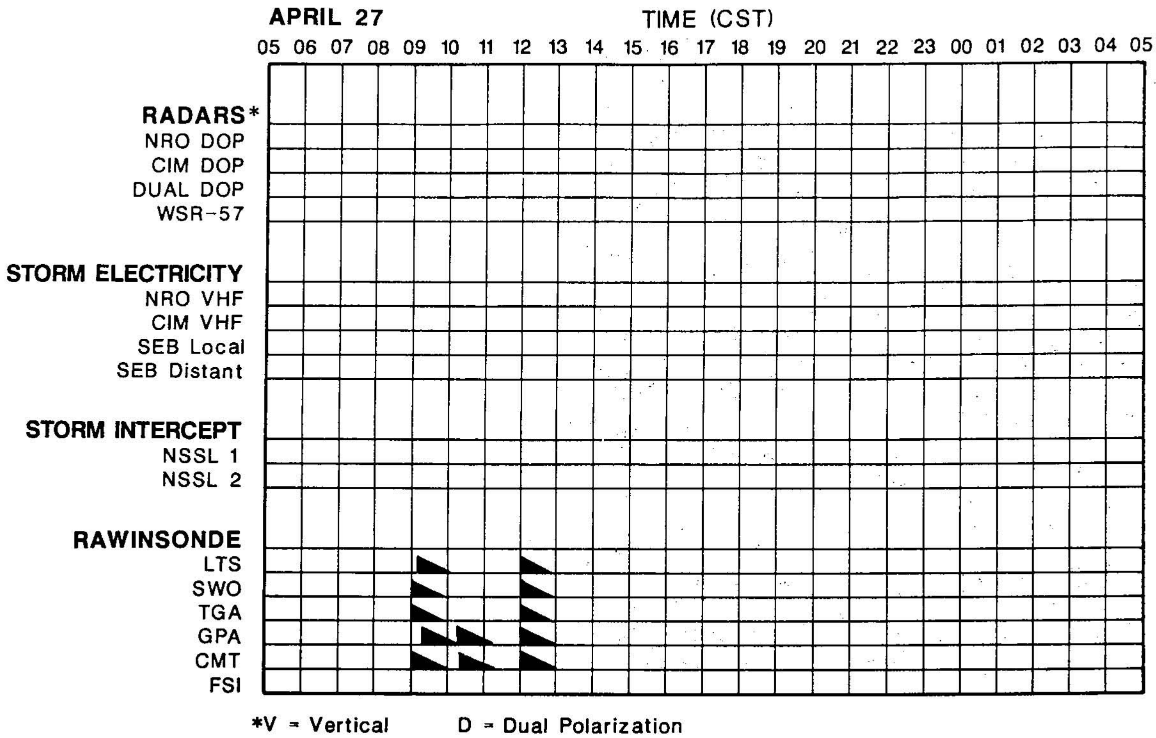


Figure 4.--Regional infrared satellite image for 1700 CST (23Z) on 26 April. Image overlaid with surface pressure (solid lines) and station observations (standard symbols) for 1700 CST. Pressures are altimeter setting analyzed in inches of Hg times 100. Bad observation in lower left caused contour packing. Analysis and graphics by POWER computer.

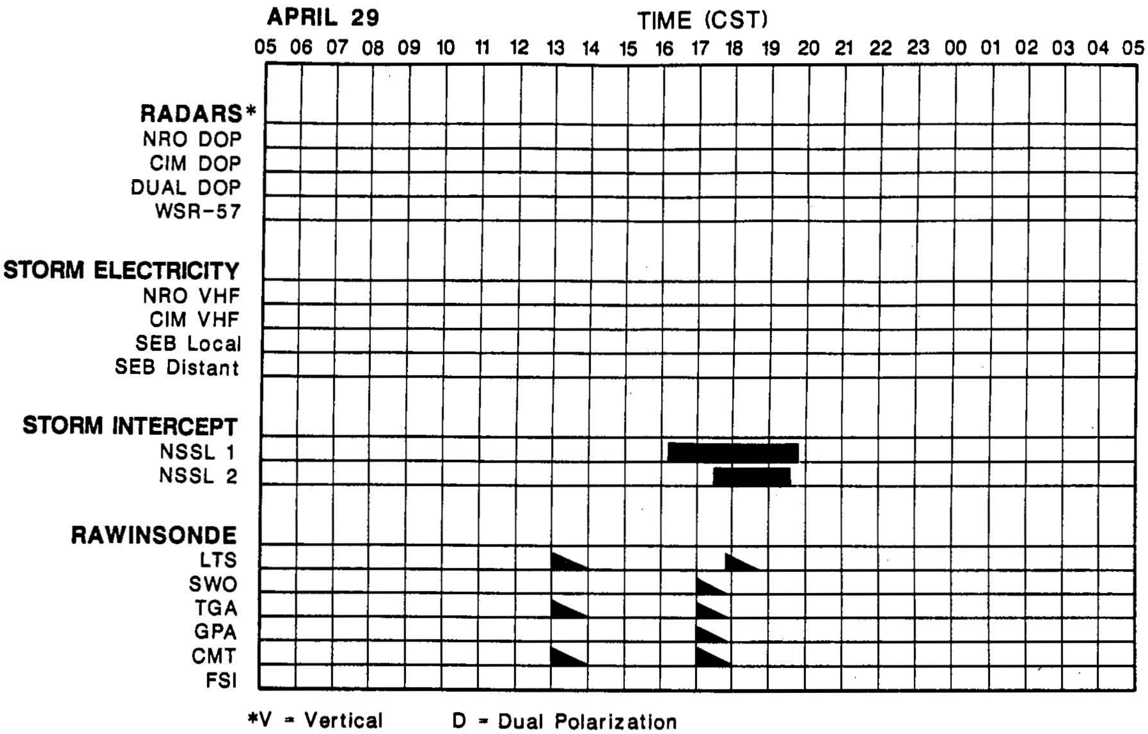
4.8 27 April - Julian day 117



4.8 Weather Summary

At 0900 CST the low was centered in northcentral Kansas and the cold front stretched through central Kansas and central Oklahoma. The thunderstorms that began on 26 April persisted and slowly progressed eastward ahead of the cold front during the morning hours. By 1330 CST the cold front was along the eastern border of Oklahoma and most of the convective activity was in Arkansas and Missouri. At 500 mb the long wave trough was centered over Colorado and a strong short wave moved over Oklahoma and Kansas in the early evening. Moisture was still present over Oklahoma and Kansas after the frontal passage. The upper-level dynamics indicated that intense convection would occur in western Oklahoma and Kansas. However, no convection occurred in response to this forcing. Numerous soundings were taken during the morning and early afternoon.

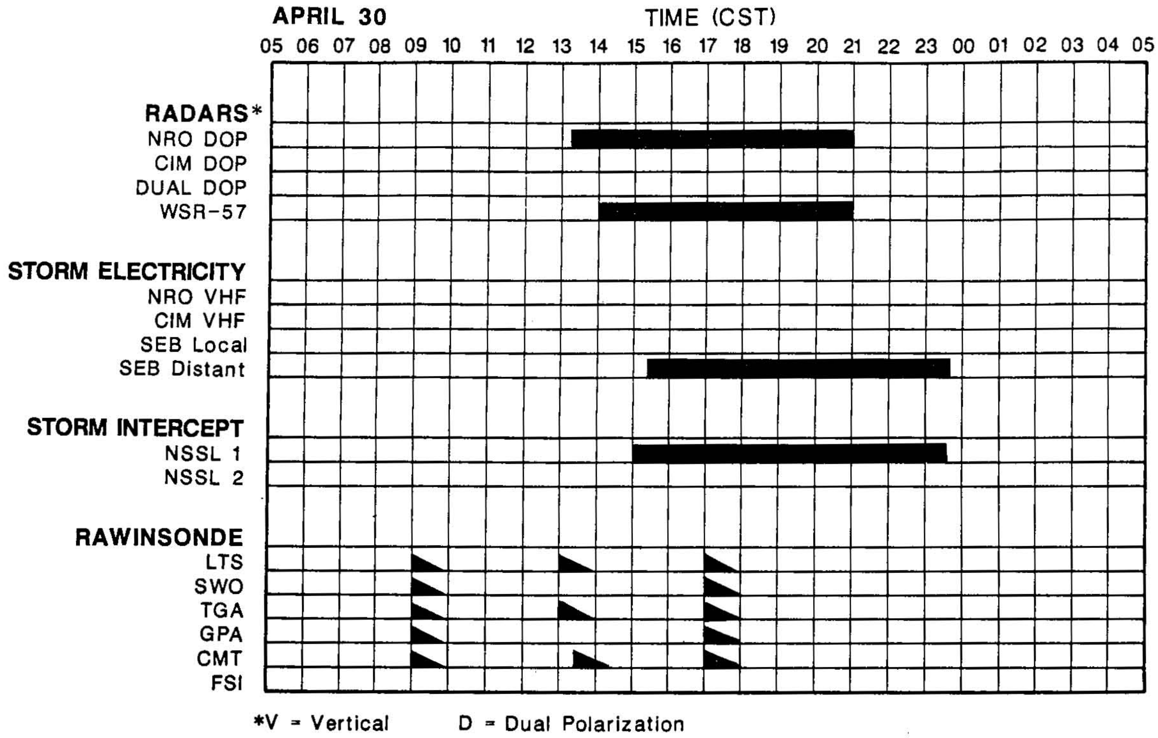
4.9 29 April - Julian day 119



4.9 Weather Summary

A low pressure system was beginning to develop on the lee side of the Rocky Mountains in the Oklahoma panhandle. A strong upper-level low had developed over Baja, California south of the main 500 mb flow pattern. A weakened shortwave was rotating around this upper low, moving northward over Texas and Oklahoma. A dryline extended from the low in the Oklahoma panhandle south into Texas. Surface dewpoints were above 60°F through much of Texas and Oklahoma. Thunderstorms formed in Texas before noon and formed in Oklahoma by late afternoon. Rawinsonde data were collected twice during the day and both of the intercept groups collected data. Unfortunately, the distance to the storms was too great to utilize the radars and Storm Electricity sensors.

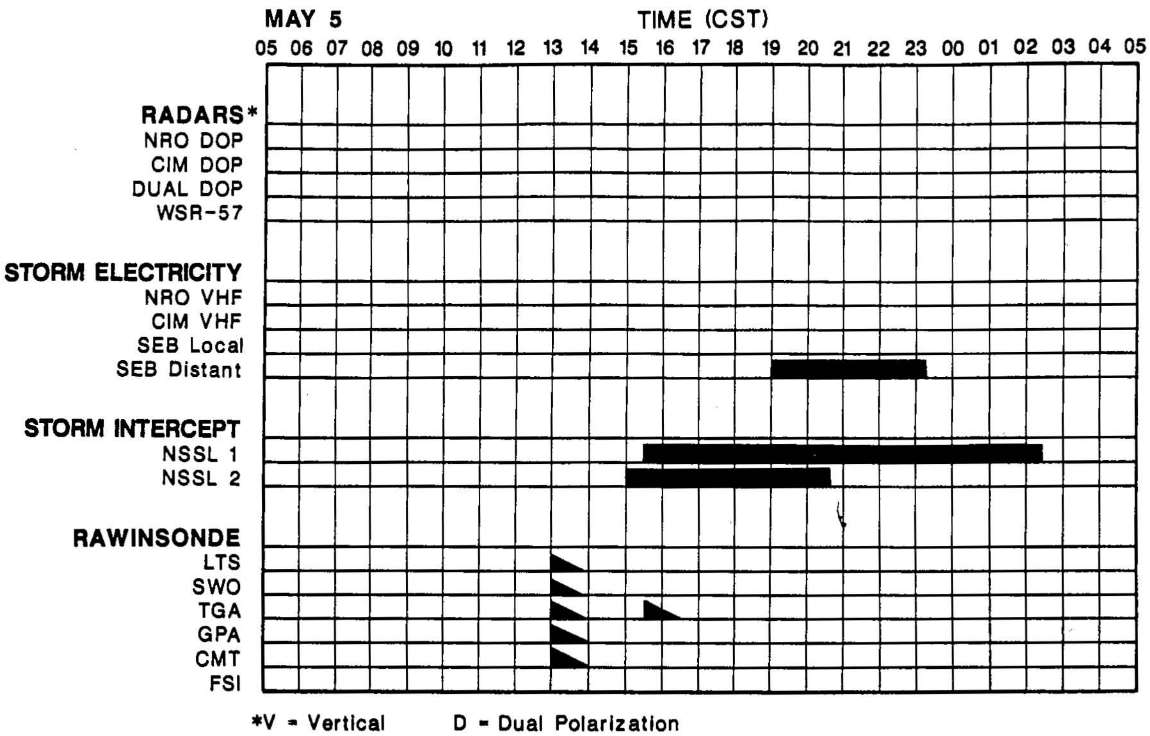
4.10 30 April - Julian day 120



4.10 Weather Summary

The upper low that was over Baja on 29 April had moved northeast into southwest Texas. The surface low was still centered in the Oklahoma panhandle with a cold front extending south into Texas. The low slowly moved eastward as the day progressed and southerly winds increased the surface dewpoints to near 70°F across most of eastern Texas and Oklhoma. A short wave was ejected northeastward by the main system in Mexico and initiated thunderstorms over Texas and Oklahoma. Thunderstorms occurred along the front and extended northward from Texas into Kansas. Data were collected from rawinsondes, the Norman radars, the Storm Electricity sensors and the Storm Electricity Intercept Group. Severe weather was not reported from the storms.

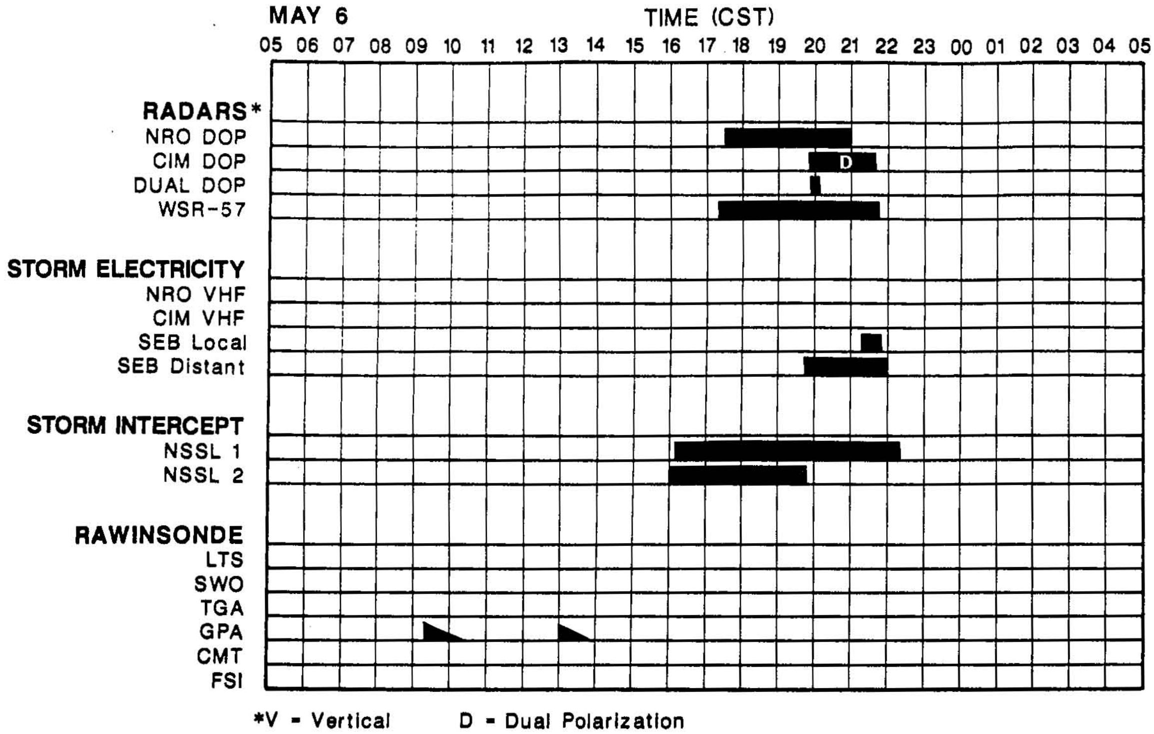
4.11 5 May - Julian day 125



4.11 Weather Summary

A long wave trough, destined to bring several severe weather days to the plains, was beginning to develop over the western United States. A preliminary short wave was ejected northeastward through the central plains with a trailing cold front across Kansas. A weak frontal wave existed in south central Kansas and a dryline extended southward from the low across western Oklahoma. The airmass ahead of the front/dryline became quite unstable during the day with increasing moisture and considerable heating. However, a capping inversion (700-800 mb) was present in Oklahoma and it prevented dryline convection. Frontal convergence in Kansas was sufficient to break the cap and a line of severe thunderstorms formed during late afternoon in southcentral Kansas. Storm Electricity and Storm Intercept groups collected data, but the radars were not utilized due to the long range to the storms.

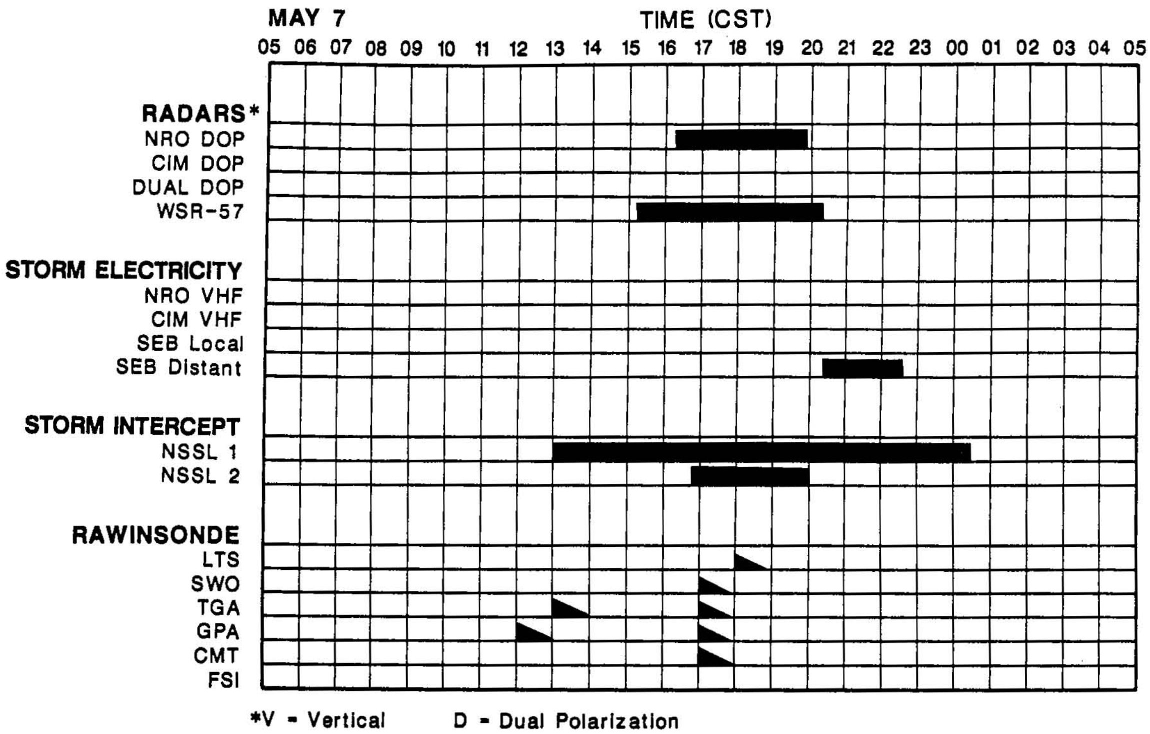
4.12 6 May - Julian day 126



4.12 Weather Summary

Conditions were much the same as the previous day. The upper trough and wavetrain were still to the west and north of Oklahoma. The front remained stationary in Kansas with a weak low present; the dryline continued its diurnal oscillation between the Texas Panhandle and western Oklahoma. The strong cap aloft remained. The result on this day was different, however, as a dryline wave formed over southwestern Oklahoma and strong low-level forcing, apparently without the benefit of a resolvable upper air system, led to the formation of deep convection. Scattered storms, one of low-precipitation type, began in western Oklahoma and progressed to central Oklahoma after dark. Activity was weakening as it passed through the dual-Doppler area.

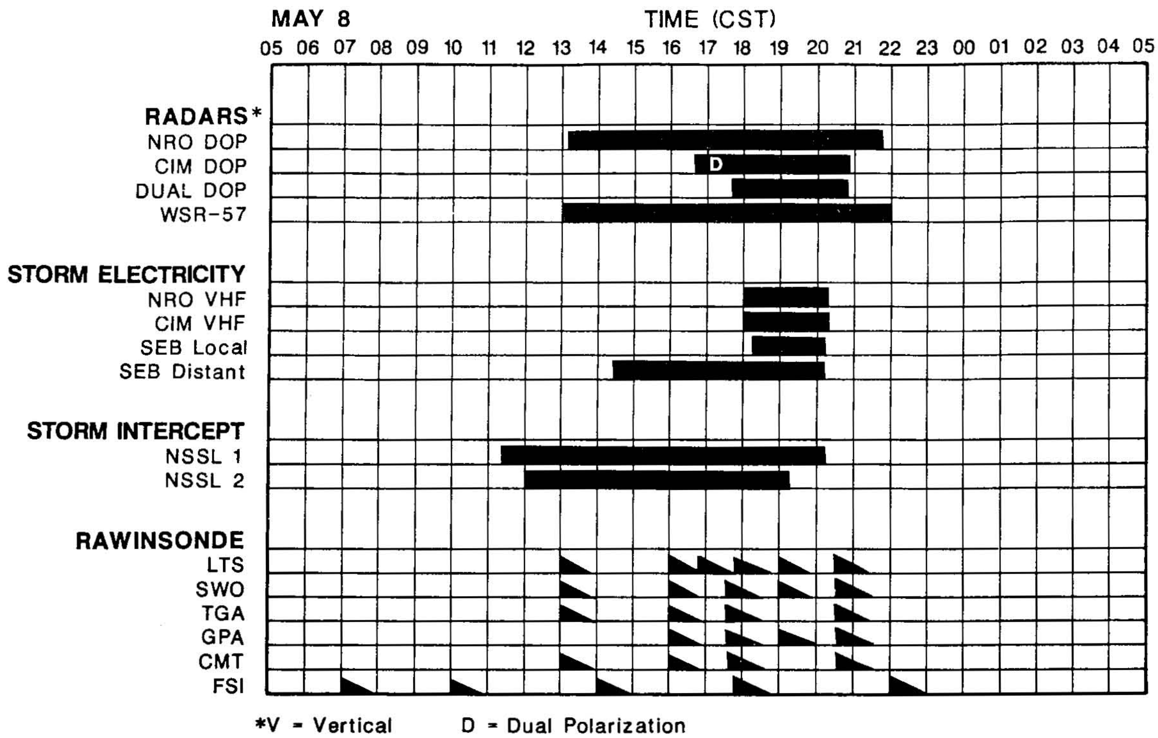
4.13 7 May - Julian day 127



4.13 Weather Summary

The western U.S. long wave trough progressed slightly eastward as a stronger short wave disturbance ejected northeastward from the base of the trough through the high plains area. The upper system interacted with the dryline convergence zone to produce severe afternoon and evening convection. Winds aloft began to back, which limited the eastward progression of the dryline to the eastern half of the Texas panhandle. The result was stronger storms that formed further west earlier in the day and moved more to the north, not affecting central Oklahoma. One of the storms, scanned at long range by the Norman Doppler, became a supercell and produced several significant tornadoes near Canadian, Texas.

4.14 8 May - Julian day 128



4.14 Weather Summary

A strong short wave trough, initially at the base of the now more meridional larger trough (western New Mexico), moved north-northeastward across the plains during the afternoon. The passage of this stronger system moved the dryline further east (western Oklahoma) and lifted the airmass, reducing the capping inversion, and increasing vertical wind shear. By afternoon, soundings revealed that the environment over central Oklahoma was conducive to severe convection (Fig. 5). A line of strong storms formed by noon and moved across Oklahoma during the afternoon and evening with many severe weather reports (Fig. 6). One particular storm, ahead of other activity, developed just west of Norman and moved across the Oklahoma City metropolitan area. A mesocyclone formed and produced two tornadoes, one doing severe damage in Edmond, Oklahoma. Much data including rapid-scan dual Doppler sequences were collected on this storm during a large portion of its lifetime.

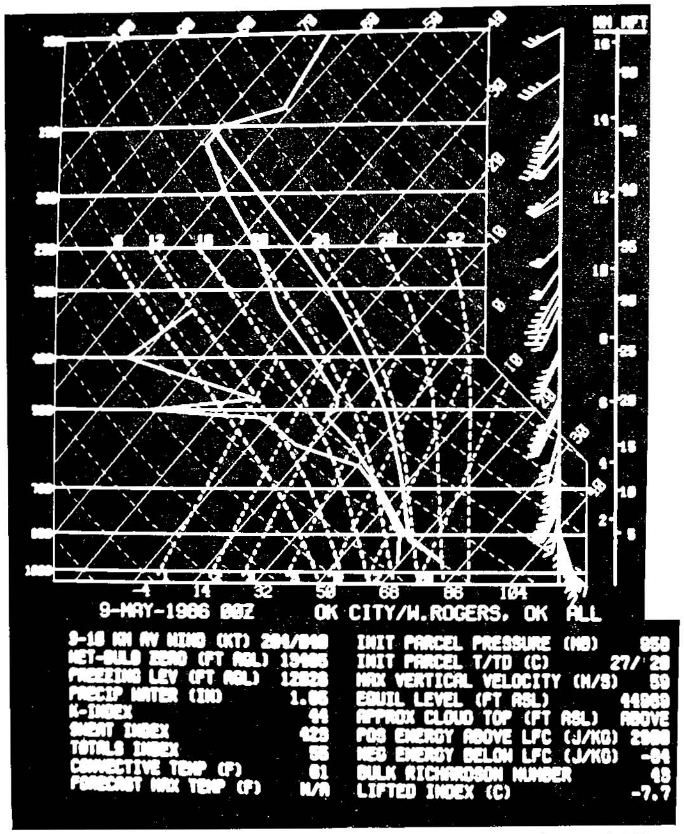


Figure 5.--Same as Fig. 3 except at 1800 CST on 8 May.

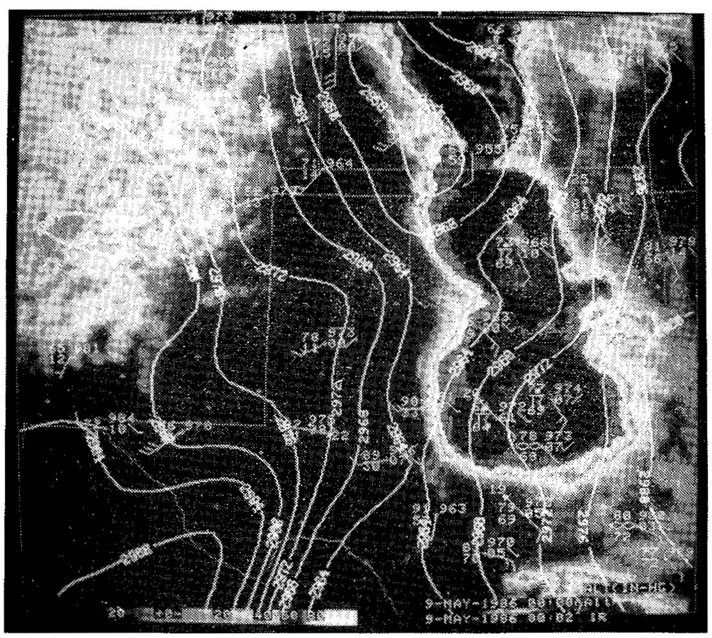
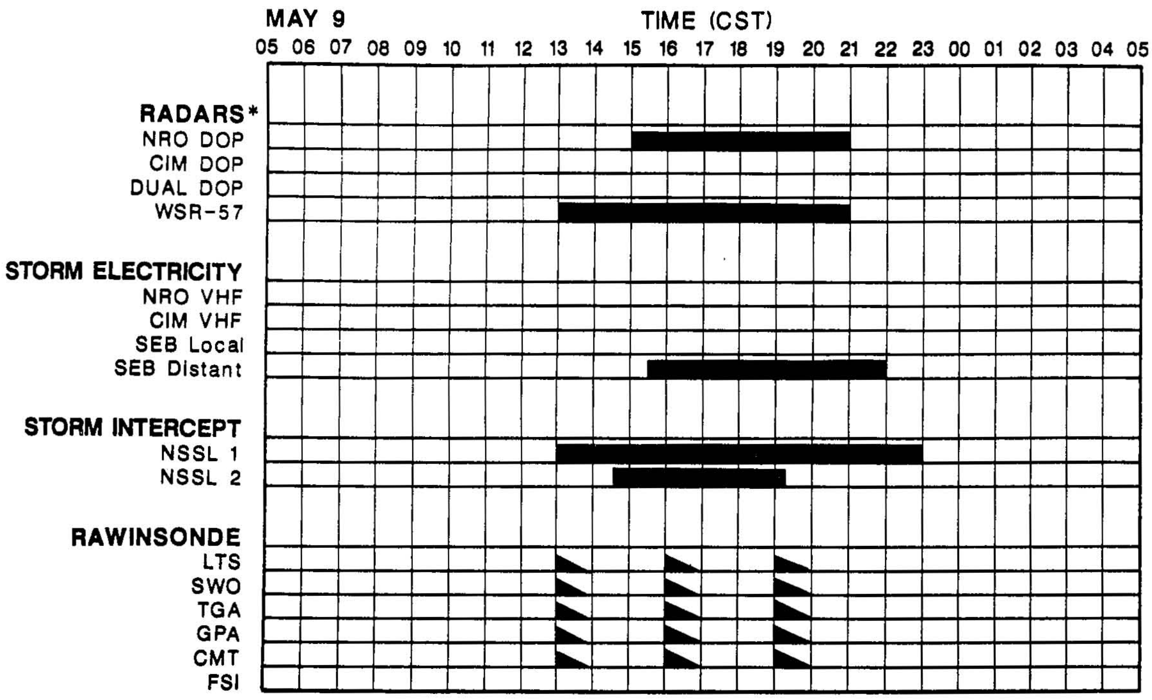


Figure 6.--Same as Fig. 4 except all data for 1800 CST on 8 May.

4.15 9 May - Julian day 129



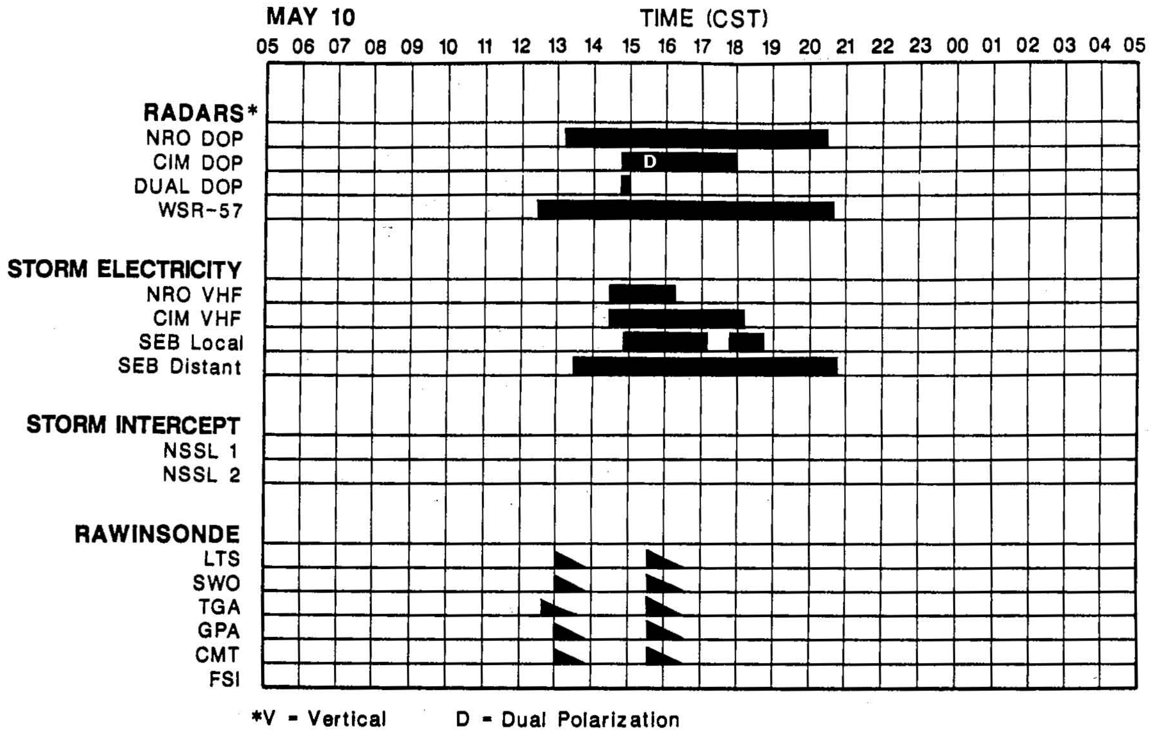
*V - Vertical D - Dual Polarization

4.15 Weather Summary

On this day the atmosphere over Oklahoma continued to be perturbed from the previous night's convection. An ill-defined front in western Oklahoma remained stationary during the morning and early afternoon before retreating westward by dark. The airmass ahead of the front was less unstable than in previous days because rain-cooled air dominated and the flow of fresh gulf air was cut off by widespread thunderstorm activity in Texas. Aloft, the high amplitude trough over the Rockies continued, but the vertical shear was weak and no significant wave activity affected Oklahoma.

During the afternoon, thunderstorms formed along the front in southwestern Oklahoma where slightly greater instability existed. NSSL sensors focused on this activity during the afternoon. The storms were generally non-severe and did not move close to the radars.

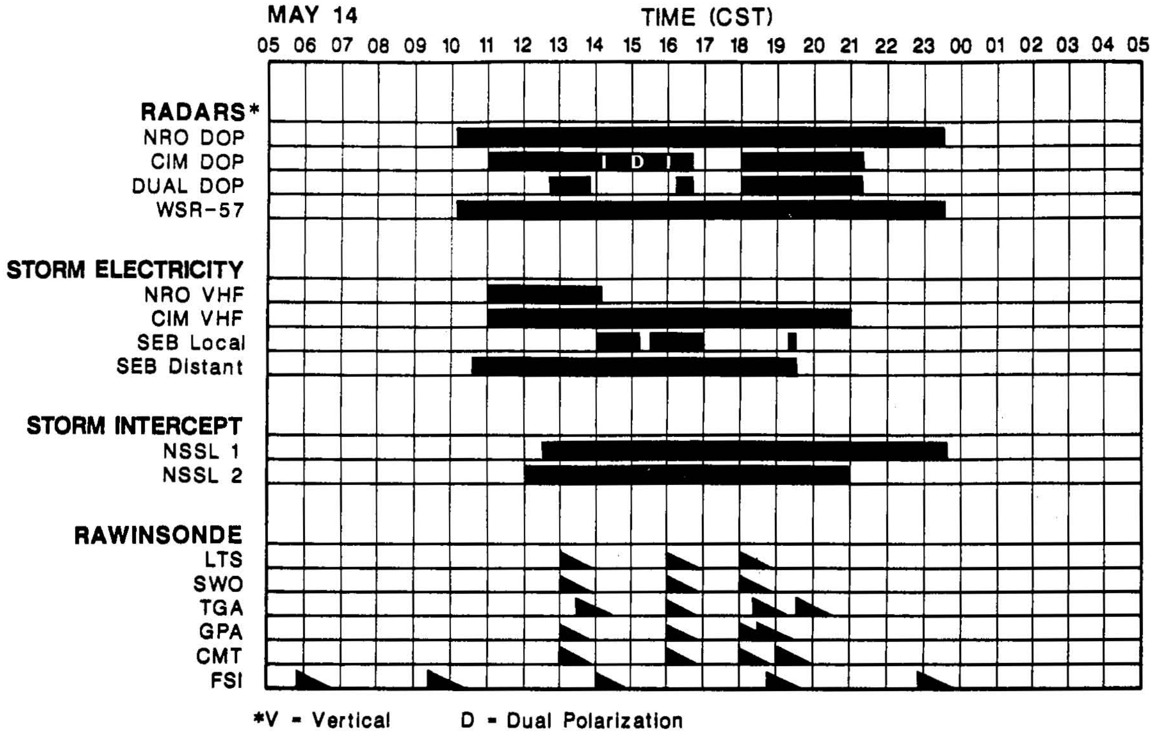
4.16 10 May - Julian day 130



4.16 Weather Summary

The upper air system that had held stationary to the west of Oklahoma for several days finally began to move eastward over the plains. However, the weakening nature of the system was evidenced by lessening vertical wind shear and very light low-level wind speeds. Although a continuous source of moisture-rich gulf air had not redeveloped, residual moisture, morning heating and relatively cool air aloft combined to produce a moderately unstable airmass.

Storms developed along the advancing cold front early in the afternoon and spread across the state with some severe weather but no tornadoes. NSSL sensors were operative when the storm line passed through central Oklahoma from mid to late afternoon.



4.17 Weather Summary

The western U.S. trough was reinvigorated by a strong system dropping southeastward from the gulf of Alaska. This strong system ejected a short wave, that had been over the southwest U.S., into the central plains. The ejected wave interacted with a stationary front and an extremely unstable airmass over Oklahoma (Fig. 7) to produce a very significant severe weather outbreak, beginning before noon and continuing until nearly midnight. In all, there were reports of 118 severe thunderstorms, 8 tornadoes and considerable flash flooding in the state.

Thunderstorm activity began along and north of the southwest-northeast oriented stationary front during late morning. Several short storm lines passed near the radars and were sampled during early afternoon. At mid-afternoon, a final larger-scale line formed over central Oklahoma as well as more isolated cells in southwest Oklahoma and northwest Texas (see Fig. 8). The large central Oklahoma MCS, including a trailing stratiform region, was sampled during late afternoon and evening. Also, a supercell storm near Snyder, Oklahoma was sampled as it produced three tornadoes viewed by intercept teams. Finally, an even stronger supercell storm was viewed by radar and intercepted before dark in Texas, southeast of Wichita Falls.

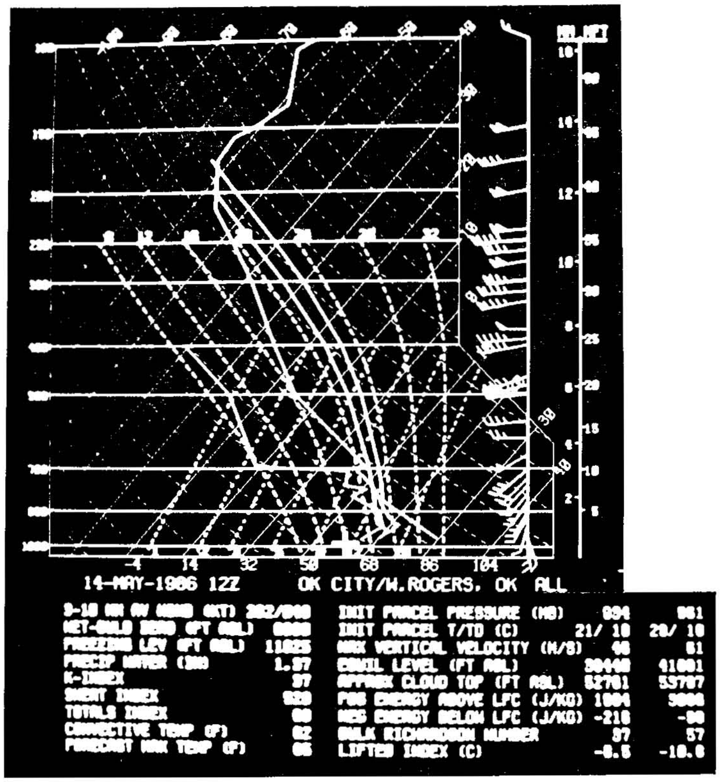


Figure 7.--Same as Fig. 3 except at 0600 CST on 14 May. Rightmost parameter listing for forecast afternoon conditions.

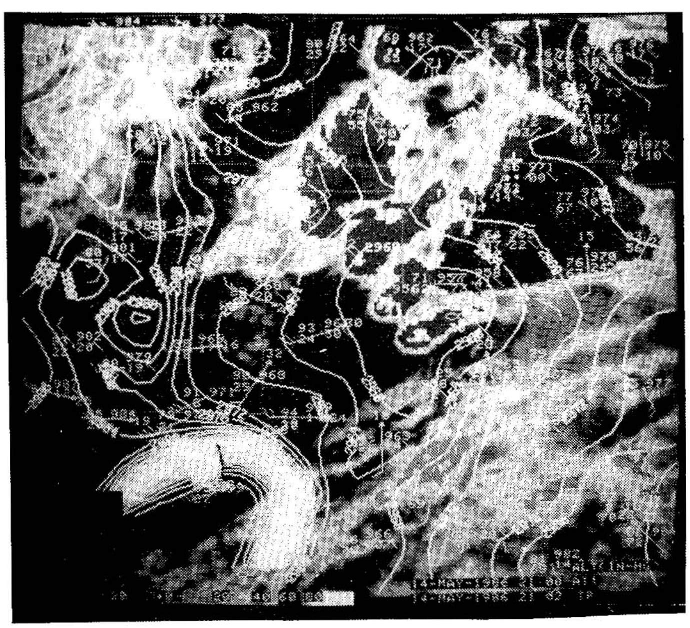
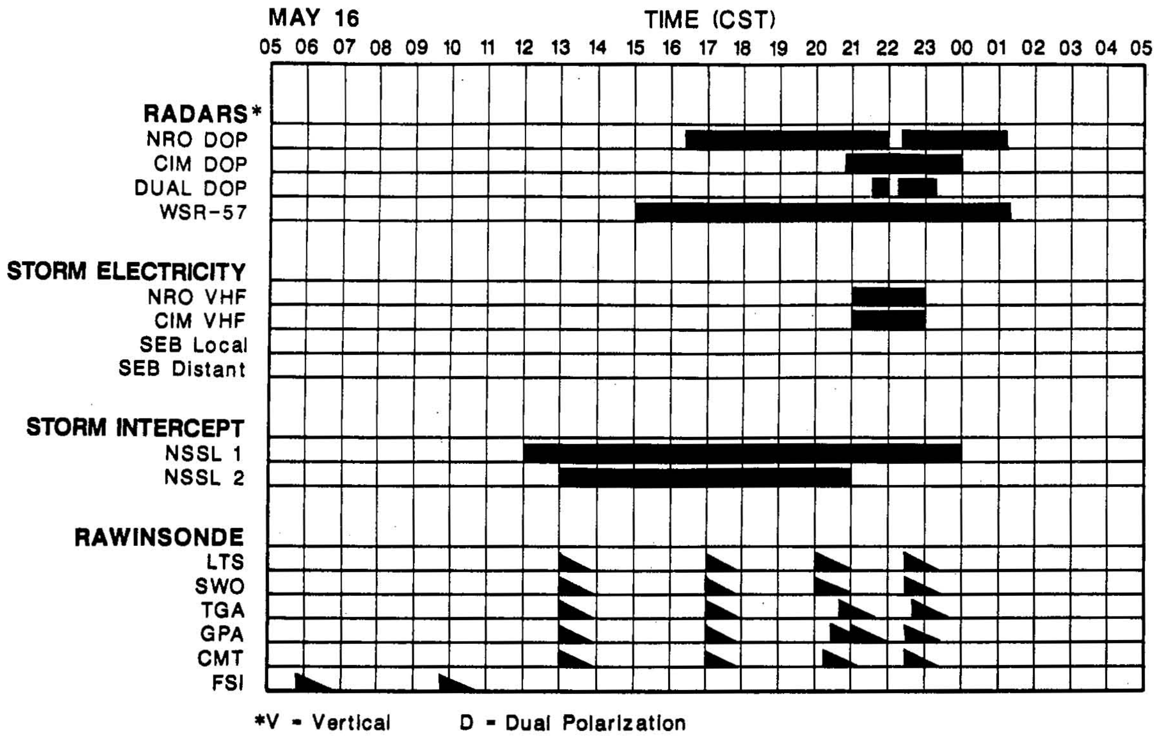


Figure 8.--Same as Fig. 4 except all data for 1500 CST on 14 May. Bad observation in lower left produced contour packing.

4.18 16 May - Julian day 136



4.18 Weather Summary

The large-scale upper air pattern that had been in effect for two weeks began to change on this day. The western U.S. upper trough moved to the plains states with wave cyclone development over southeast Colorado. During the day, the low tracked across Kansas and a strong cold front began sweeping across Oklahoma by late afternoon. Aloft, a short wave, initially over Arizona, moved eastward toward the state, developing a secondary surface low in northwest Texas. These conditions, when combined with the continuing extremely unstable airmass (Fig. 9), caused Oklahoma to experience its second significant severe weather outbreak in three days.

Afternoon storm development was along the cold front from near Salina, Kansas to west of Childress, Texas. Although some isolated supercell development occurred near Childress, the convection quickly took the form of a large classical MCS, marching across Oklahoma during the nighttime hours (Fig. 10). Much severe weather, including 11 weak tornadoes, accompanied the convective leading edge of the system. Most NSSL sensors were active as the system propagated through central Oklahoma during the hours surrounding midnight. A good data set was obtained, flawed only by a temporary interruption of Norman Doppler operations caused by power generator failure.

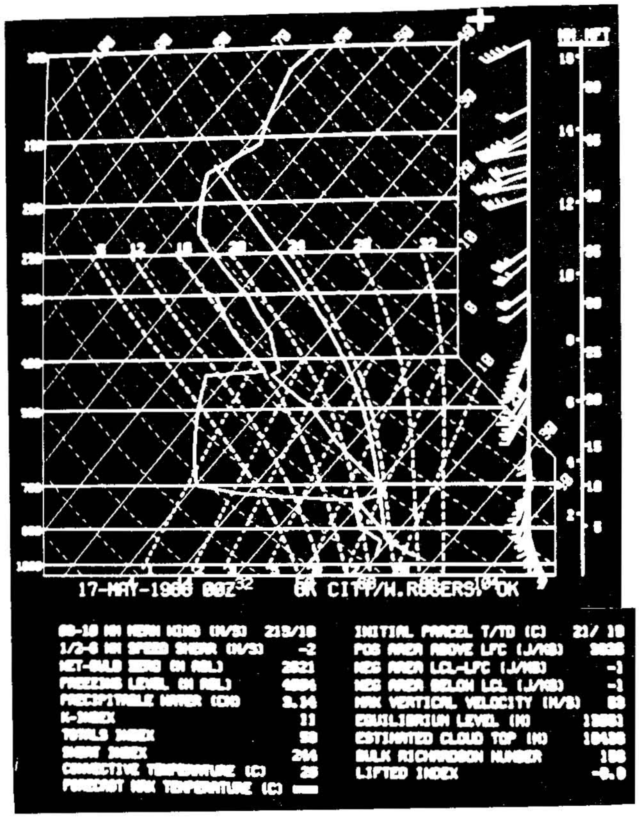


Figure 9.--Same as Fig. 3 except at 1800 CST on 16 May.

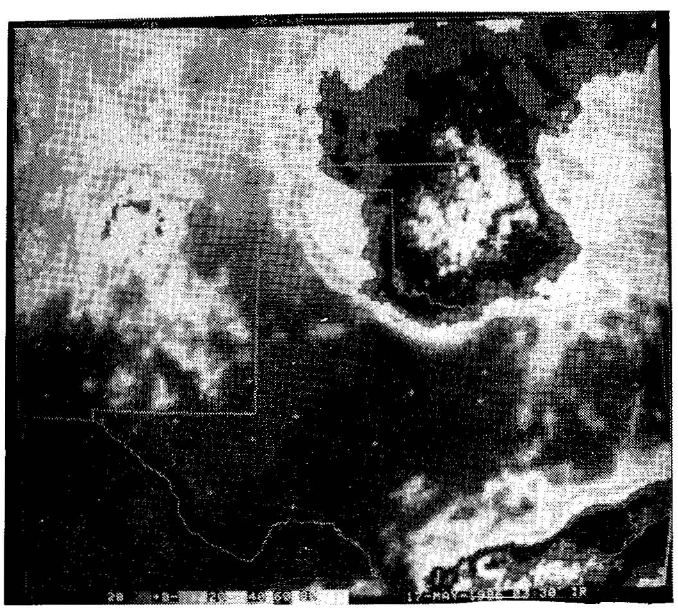
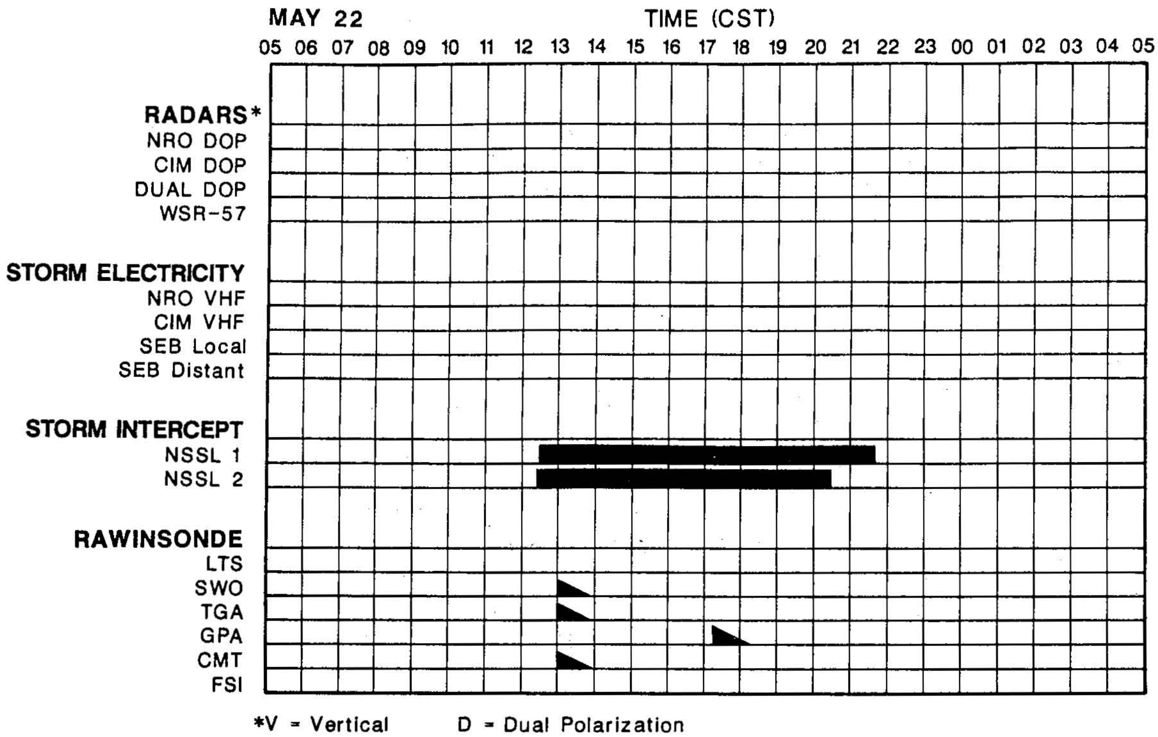


Figure 10.--Regional infrared satellite image for 2130 CST (0330Z) on 16 May.

4.19 22 May - Julian day 142

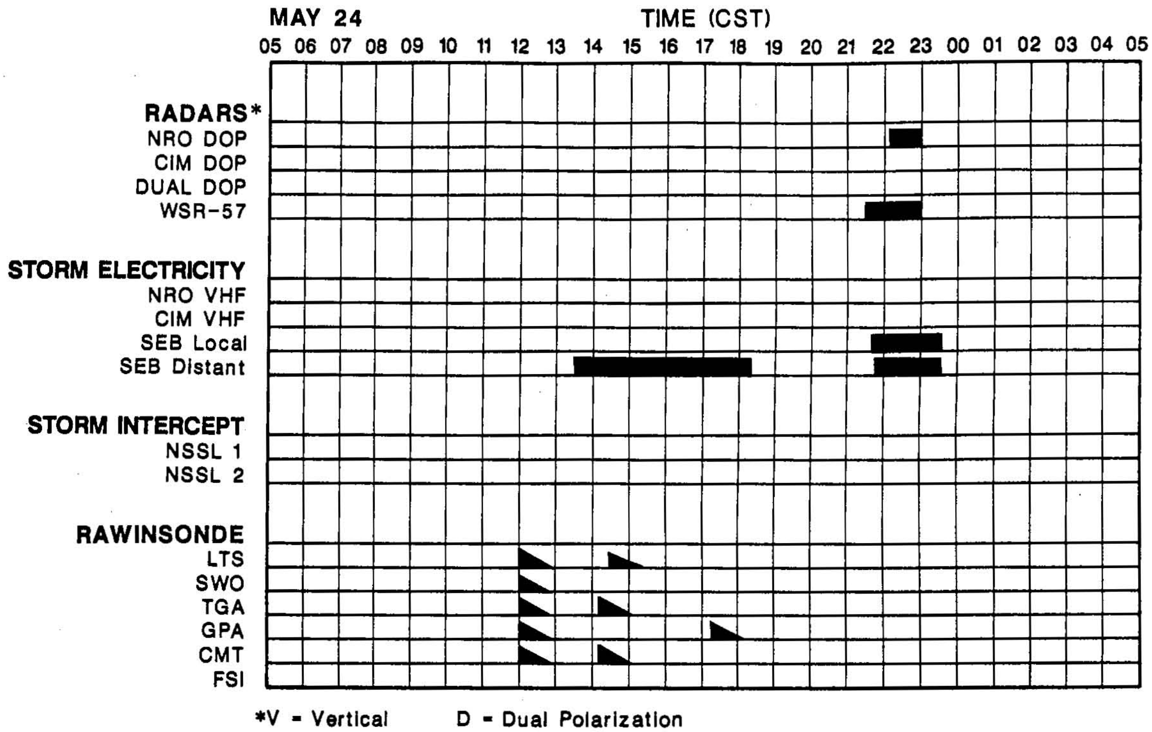


4.19 Weather Summary

A strong ridge and accompanying warm air aloft had been dominating Oklahoma's weather for several days. On the morning of the 22nd, a weakening upper trough approached the central U.S. ridge from the west. In response to the trough, a well-defined surface low and triple point between warm front, cold front and dryline developed in northwest Oklahoma during the day. Low-level moisture, although initially shallow, and strong heating produced a moderately unstable atmosphere. With the approach of the upper system and forecast deep tropospheric rising motion, potentially severe thunderstorms were anticipated and sensors were made ready to collect data.

The forecast rising motion did not occur during the afternoon as the upper trough weakened faster than expected and moved more slowly. Due to the lack of lifting, moisture remained shallow beneath a strong capping inversion. Although the surface parameters looked promising all afternoon, deep convection failed to develop. Operations were cancelled by late afternoon.

4.20 24 May - Julian day 144

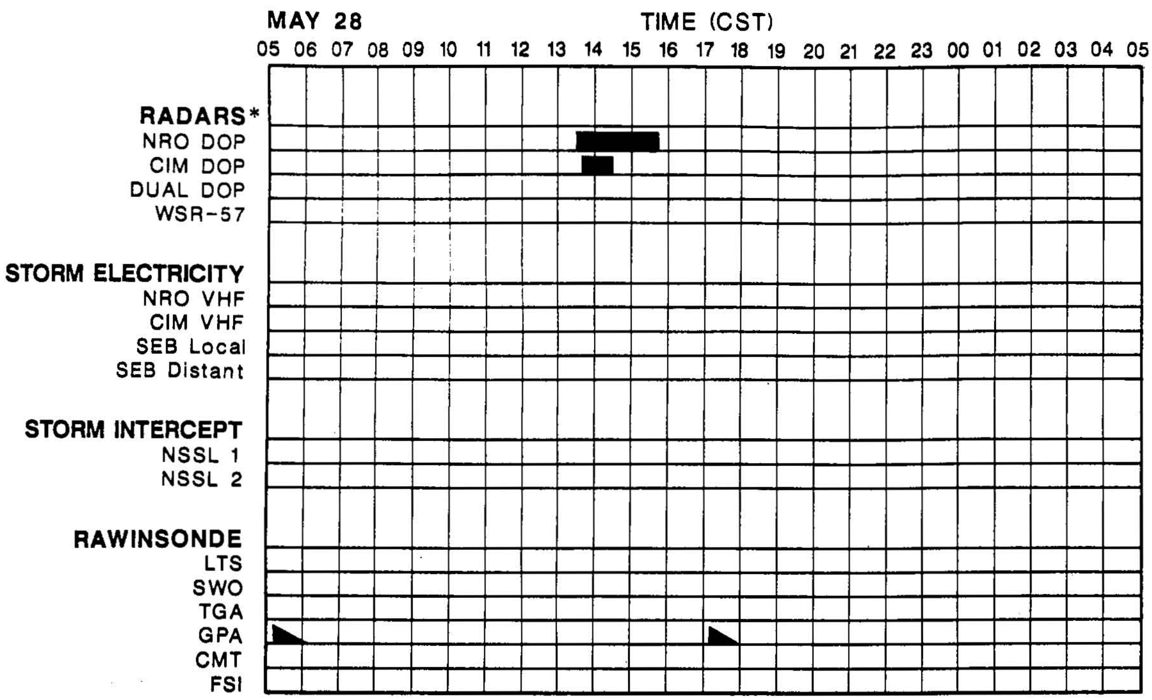


4.20 Weather Summary

A cold front that had passed through central Oklahoma the previous day was stationary from southeast Oklahoma into north Texas. The cold air was shallow across most of Oklahoma with an elevated frontal zone extending across the northern part of the state. Considerable moisture was initially present, but morning thunderstorms began along the Red River and spread southeastward into Texas, interrupting moisture flow into most of the state except the southwest section.

Afternoon storms formed in the Texas Panhandle ahead of an approaching upper wave and in an area of upslope flow. Some heating and moisture return from southwest Oklahoma combined to form an atmosphere which was unstable enough to support a few severe hailstorms along the western Oklahoma border and along the elevated boundary in northwest Oklahoma. Storms weakened as they moved into a more stable environment over central Oklahoma after dark.

4.21 28 May - Julian day 148



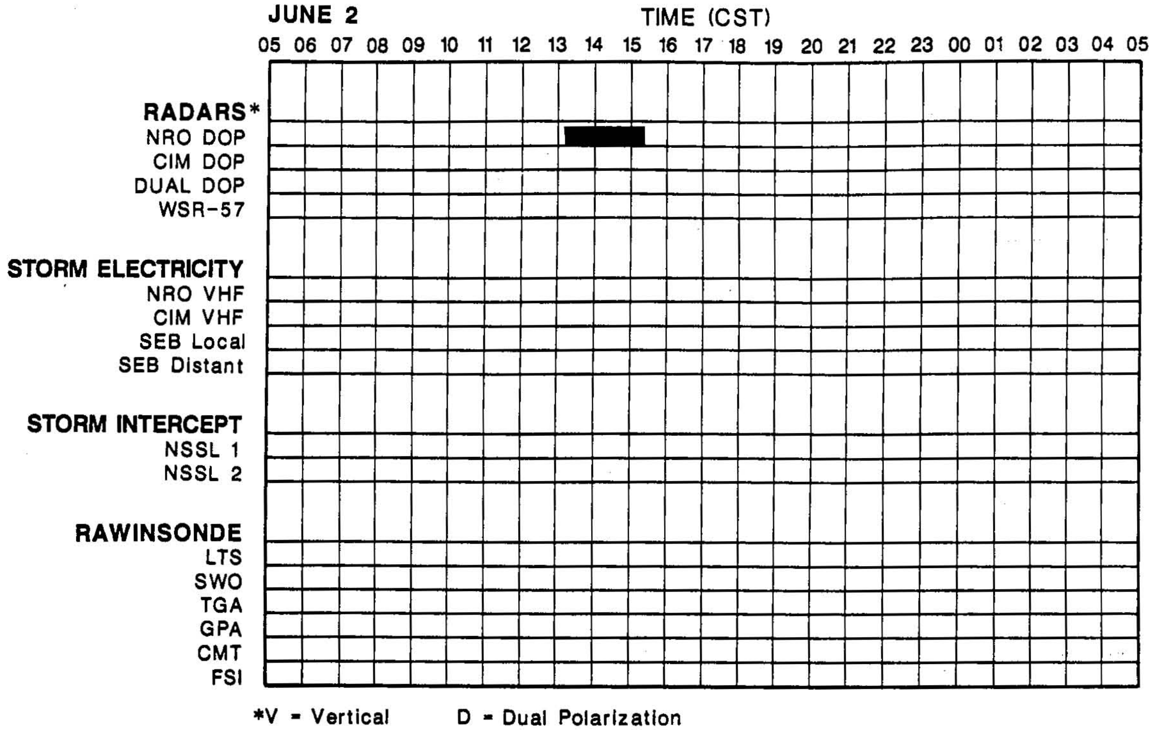
*V - Vertical D - Dual Polarization

4.21 Weather Summary

A cold-core, cut-off 500 mb low that had formed over the northcentral U.S. and drifted southward was situated over Kansas. No strong fronts or low-level discontinuities were present, but minor perturbations aloft were rotating around the upper system and provided periods of weak rising motion. Modest moisture combined with cold mid-level temperatures (-18°C at 500 mb) to produce enough instability for thundershowers.

NSSL radars operated in early afternoon as weak thunderstorms developed on a scattered basis in central and northern Oklahoma. Data collection was discontinued when the convection failed to be significant.

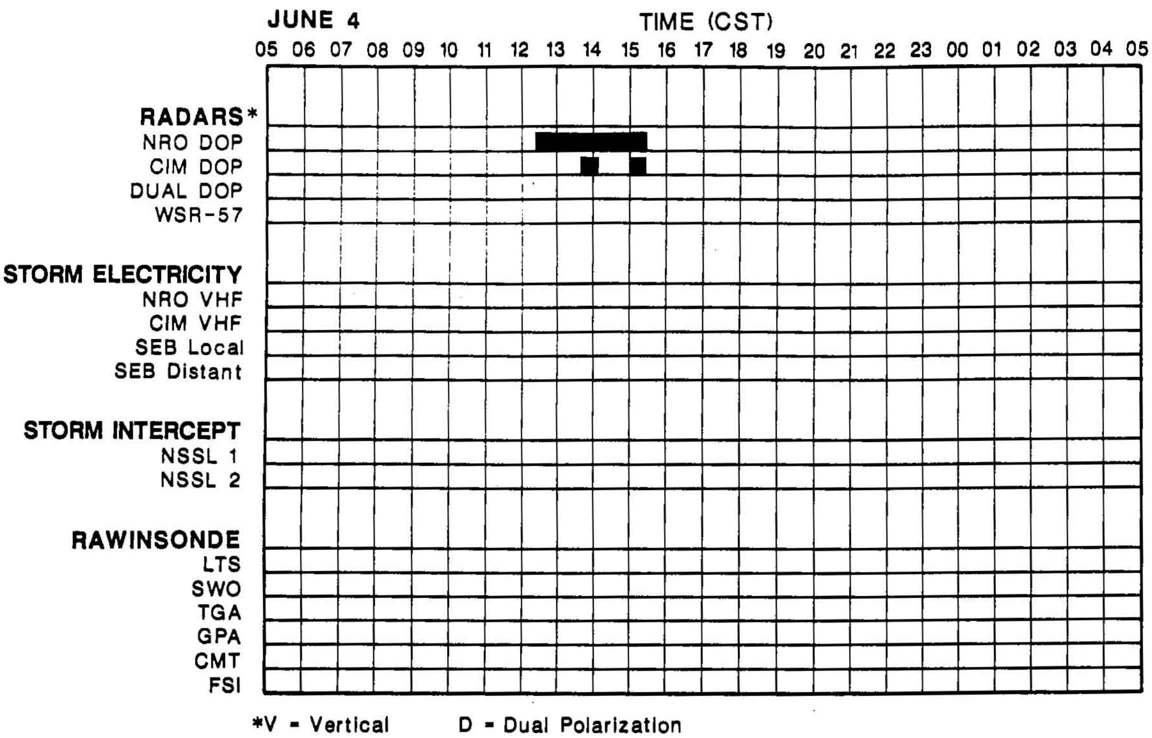
4.22 2 June - Julian day 153



4.22 Weather Summary

The western U.S. was dominated by a nearly zonal flow pattern at 500 mb with a weakened upper low over New Mexico. A surface high-pressure center was over the Great Lakes and a cold front extended in an east-west direction from Philadelphia, Pennsylvania to Springfield, Missouri to Wichita, Kansas to Cheyenne, Wyoming. The surface dewpoints were above 60° F south of the front throughout all of Oklahoma and Texas. The winds at 500 mb were diffluent and moderate convection and some thunderstorms occurred over most of Oklahoma, Kansas and eastern Texas. The Norman Doppler radar collected data for the DOOM project.

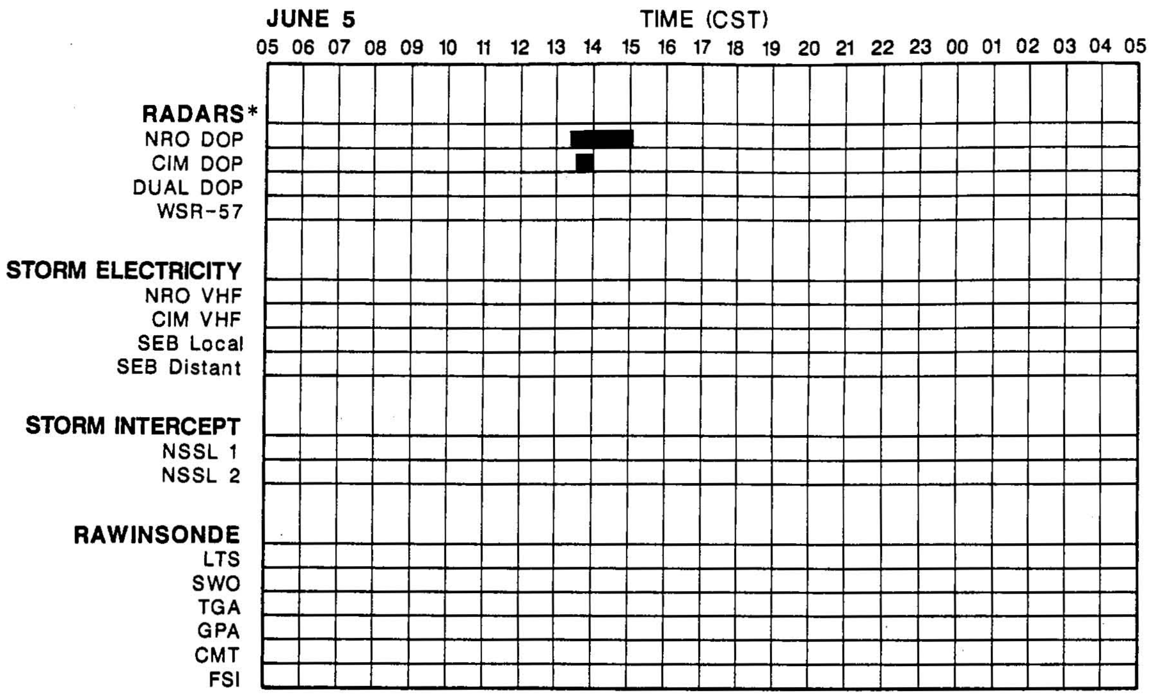
4.23 4 June - Julian day 155



4.23 Weather Summary

Canada and the far northern plains were dominated by high pressure, but a weak upper low centered over Nebraska still dominated the southern plains. Surface dewpoints remained high throughout Oklahoma, Texas and Kansas. The upper low continued to shed short waves and caused widespread convection in Oklahoma, Kansas and Texas. Both the Norman and Cimarron Doppler radars collected data.

4.24 5 June - Julian day 156

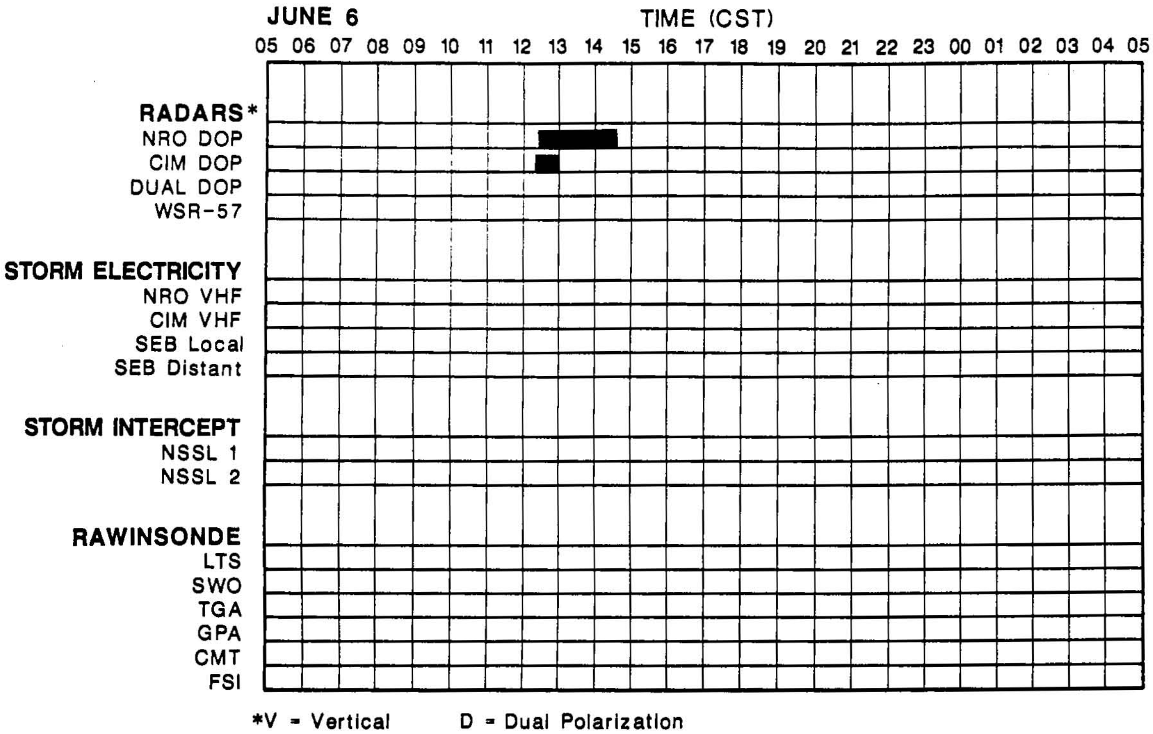


*V = Vertical D = Dual Polarization

4.24 Weather Summary

The upper low at 500 mb had moved south and by 0600 CST was centered over the Oklahoma panhandle. A situation similar to 4 June occurred with high temperatures and dewpoints at the surface, but weak upper-level support. A stationary front cut through northwestern Oklahoma and defined a western boundary for convective activity. As before, widespread, moderate convection occurred over the eastern two-thirds of Oklahoma, eastern Texas and most of Kansas. Data were collected for the DOOM project using the Norman and Cimarron Doppler radars.

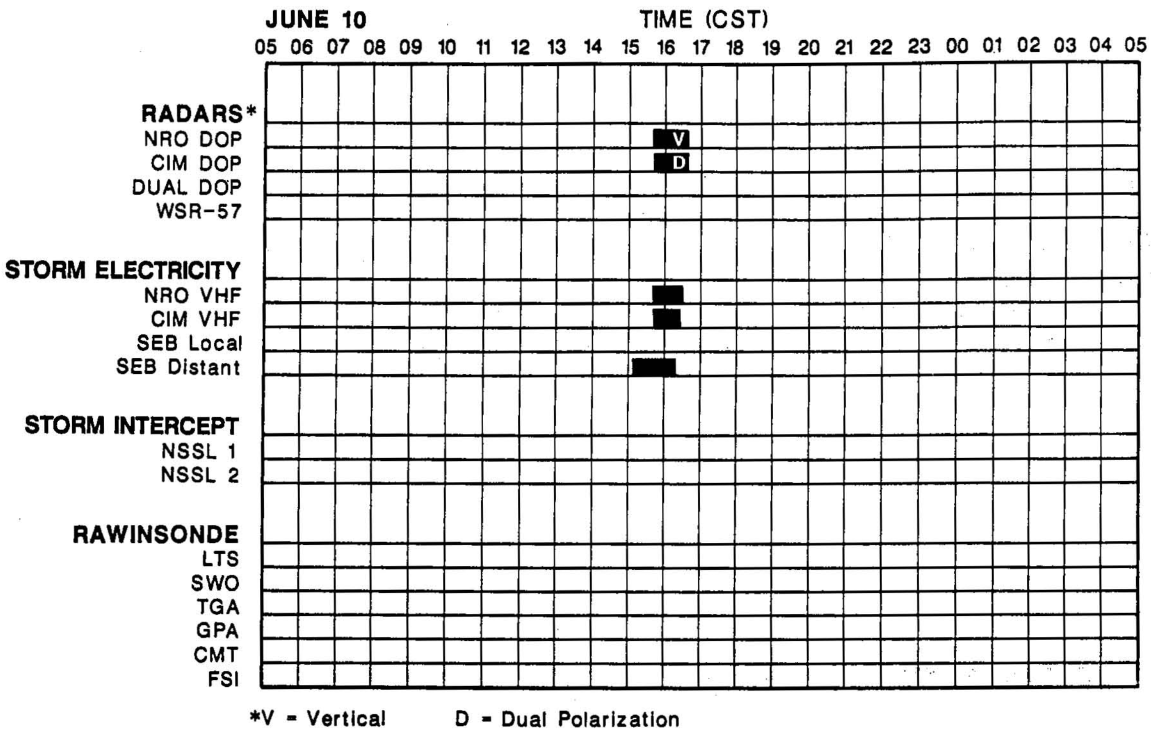
4.25 6 June - Julian day 157



4.25 Weather Summary

The quasi-stationary front had moved slowly northward during the previous day and was in Kansas at 0600 CST. The 500 mb low was centered over the Kansas-Missouri border and was forecast to move northeastward within the next 24 hours. Again, the surface temperatures and dewpoints were high and widespread convection occurred in connection with weak forcing aloft. Both Doppler radars collected data.

4.26 10 June - Julian day 161



4.26 Weather Summary

A surface low was in northcentral Nebraska with a cold front extending through central Kansas, western Oklahoma and the Texas panhandle. A 500 mb trough was over Colorado with an upper jet entering into Kansas and Nebraska. Southerly winds brought warm, moist air from the gulf northward into Nebraska. In Oklahoma, thunderstorms, some severe, developed ahead of the front throughout the central portions of the state. The Norman Doppler radar collected data in the vertically pointing mode and, in conjunction, the Cimarron Doppler radar collected data in the dual polarization mode. Data were also collected by the Norman and Cimarron VHF and the other Storm Electricity sensors.

ACKNOWLEDGMENTS

The successful completion of the NSSL 1986 Spring Program was due to the cooperation of all who were involved in the Program planning, observational coordination, instrument operations, and data recordings. We are particularly grateful for the cooperation and dedication of the personnel from the U.S. Air Force Sixth Weather Squadron Mobile, the U.S. Army Field Artillery Board, the 75th Field Artillery Brigade, and the 212th Field Artillery Brigade, who carried out rawinsonde network operations.

The authors wish to thank the entire NSSL staff for their assistance in gathering information on the wide variety of data collected, the general quality of the data, and the methods of data collection. We are indebted to the principal investigators of each experiment who wrote the objectives found in Section 2. We also thank Sandra McPherson for typing and management of manuscript preparation, Joan Kimpel for drafting support, and Charles Clark for photographic support.

APPENDIX A

Data Collection on Days Without Storms

The data listed here are for days during which no storms occurred, but some potential for severe weather was perceived by the NSSL forecasters. Most of these data are limited to one or two early afternoon soundings on a given day; however, on some days several soundings were taken at progressively later times to monitor developing weather conditions, and the Storm Intercept groups left NSSL with the hope of observing severe weather. The data collected on these particular days may provide an interesting comparison with the data collected on storm days. All times listed are Central Standard Time.

2 April

1400	rawinsonde launched from TGA
1317 to 1832	NSSL 1 on storm intercept
1530 to 1744	NSSL 2 on storm intercept

11 April

1400	rawinsondes launched from LTS, SWO, GPA and CMT

22 April

1400	rawinsonde launched from GPA

24 April

1100	rawinsonde launched from GPA
1400	rawinsonde launched from GPA

12 May

1300	rawinsondes launched from LTS, SWO, TGA, GPA and CMT
1420 to 1916	NSSL 2 on storm intercept

15 May

1300	rawinsonde launched from LTS

21 May

1300	rawinsonde launched from GPA

23 May

1715	rawinsonde launched from GPA for profiler comparison

25 May

1300	rawinsondes launched from TGA, GPA and CMT
1724	rawinsonde launched from GPA

26 May

1715	rawinsonde launched from GPA

27 May

1300	rawinsonde launched from GPA
1715	rawinsonde launched from GPA

29 May

0515	rawinsonde launched from GPA
1300	rawinsondes launched from LTS and GPA
1715	rawinsonde launched from GPA

30 May

0515	rawinsonde launched from CMT
1300	rawinsondes launched from LTS and GPA
1715	rawinsonde launched from GPA

31 May

1413 to 1619	SEB collected data in the distant mode

APPENDIX B

NSSL Doppler Radars

Basic radar system characteristics are given in Table B.1. These represent the system configuration during the 1986 data acquisition period. Some system parameters such as transmitter power and receiver noise level are subject to some variation and are 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.

The 1986 season was the second year of testing and evaluation of the dual linear polarization technique as implemented on the CIM Radar. The technique is regarded as an auxiliary capability and data was taken on demand basis for special studies. Details of the system engineering and data acquired are available on request.

Table B.1 NSSL Doppler Radar Characteristics - Spring 1986

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	24.5 dB	22.3 dB
Polarization	Vertical or Horizontal	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

1986 DOPPLER RADAR SLANT RANGE AND GATE SHIFT CORRECTIONS

1986 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

1986 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

<u>1986 ORIENTATION ADJUSTMENTS FOR NSSL DOPPLER RADARS</u>

<u>NRO</u>

Elevation Error = $-0.007\ \phi + 0.1$

Azimuth Error = $1.0 \cos 2(\theta + 10^{o}) + 1.3$

ϕ and θ are the indicated elevation and azimuth angles.

<u>CIM</u>

Elevation Error = $-0.8\ (1 - \exp \frac{-\phi}{22}) + 0.1$

Azimuth Error = -0.35

APPENDIX C

Stationary Automated Mesonetwork (SAM)

C.1 Station Locations

The following is a list of NSSL stations used for the 1986 mesonetwork during the research period.

1986 Mesonetwork

Site	I.D.	Lat. N.	Long W.	Azimuth (degrees)	Range (km)	MSL Elev. Feet
8601	MWF	35°14'13"	97°27'43"	63.8	0.1	1175
8604	AAA	34°38'16"	99°7'23"	246.7	165.2	1352
8605	BBB	34°38'14"	98°30'55"	235.5	116.7	1292
8606	CCC	34°39'9"	98°1'5"	218.0	82.2	1237
8607	DDD	34°39'44"	97°26'24"	178.1	63.8	1085
8608	EEE	34°38'59"	96°54'52"	142.4	82.2	1256
8612	FFF	35°3'46"	99°5'46"	263.1	149.6	1555
8613	GGG	35°5'12"	98°32'59"	260.7	100.1	1420
8614	HHH	35°6'7"	97°57'43"	251.9	47.7	1148
8615	III	35°7'4"	97°29'17"	189.7	13.4	1261
8616	JJJ	35°3'17"	96°54'21"	111.6	54.5	1030
8620	KKK	35°32'24"	99°5'53"	283.3	151.9	1664
8621	LLL	35°32'12"	98°32'0"	289.3	102.5	1522
8622	MMM	35°28'44"	97°57'20"	301.3	52.1	1370
8623	NNN	35°29'45"	97°26'32"	3.8	28.9	1245
8624	OOO	35°33'30"	96°53'24"	55.3	63.1	990
8628	PPP	36°0'2"	99°5'33"	300.5	169.9	1950
8629	QQQ	36°0'52"	98°31'40"	312.3	129.3	1575
8630	RRR	35°57'26"	97°58'45"	330.0	92.7	1077
8631	SSS	36°1'44"	97°24'44"	3.0	88.2	1035
8632	TTT	35°56'18"	96°52'25"	34.2	94.5	960
8654	GPA	34°58'47"	97°31'16"	190.5	29.0	1085

Comments:

1. Add 4' to the elevation to arrive at the elevation of the instrument shelter (pressure and temperature location).

2. The azimuth and range values are calculated using the Norman NSSL Doppler as the base station.

C.2 Components of Sensor and Recording System Used in the 1986 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-dependent 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 not 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.

   The recording resolution of each sensor is basically determined by the site data logger's analog-to-digital converter and is as follows:

$$\text{sensor resolution} = \frac{\text{sensor analog range}}{[(2)^8 - 1]}$$

The accuracy of each sensor is generally a value that is smaller than the resolution.

Parameter	Range	Meteorological Resolution
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

*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.

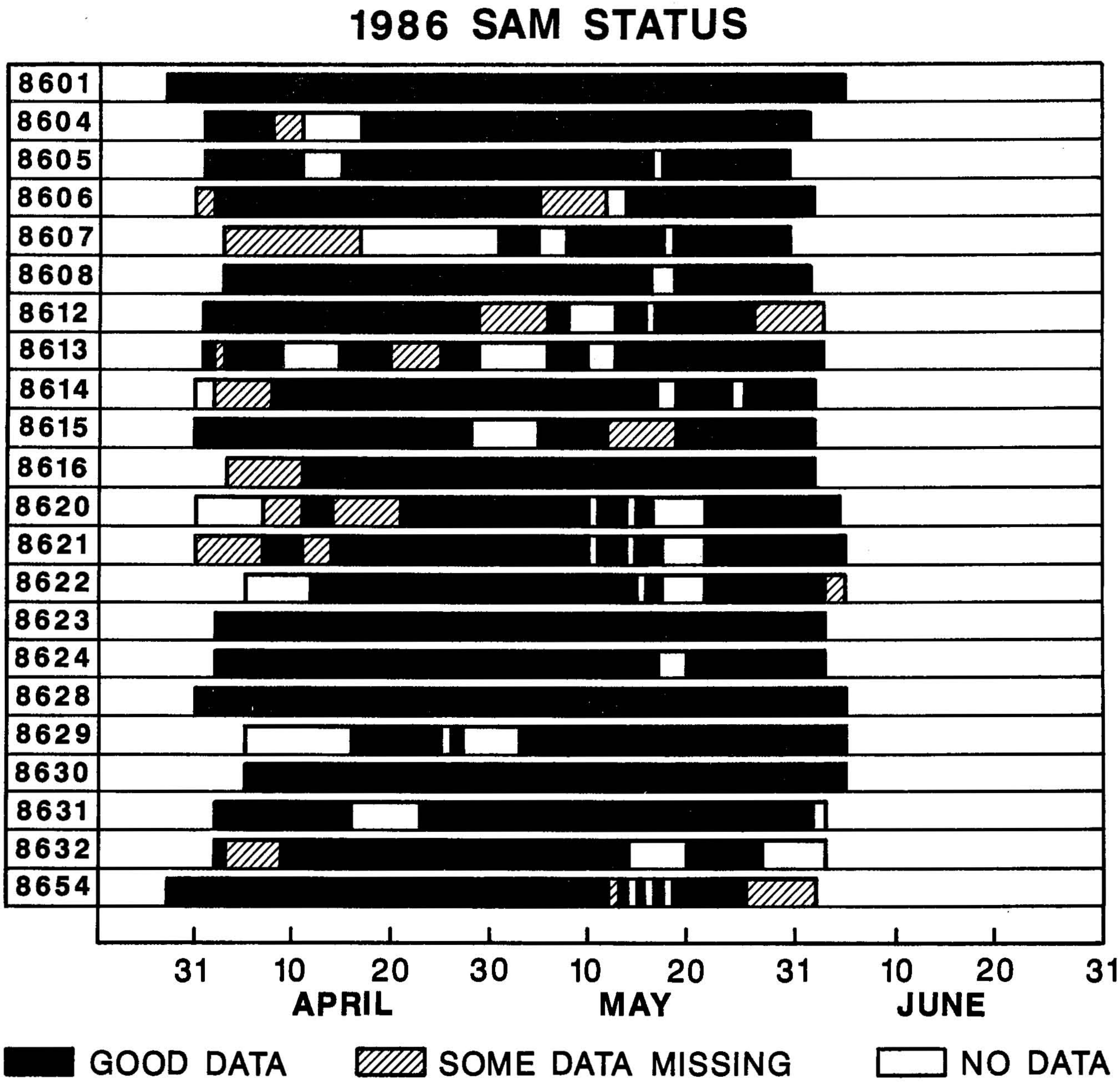


Figure 11.--Depiction of the availability and quality of the data from the 22-station mesonetwork.

NATIONAL SEVERE STORMS LABORATORY

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

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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)

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

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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)

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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)

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