NOAA Technical Memorandum ERL NSSL-78

# OBJECTIVES AND ACCOMPLISHMENTS OF THE NSSL 1975 SPRING PROGRAM

## PART I: OBSERVATIONAL PROGRAM

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K. Gray
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## PART II: RADAR QUALITY CONTROL PROGRAM

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National Severe Storms Laboratory
Norman, Oklahoma
July 1976

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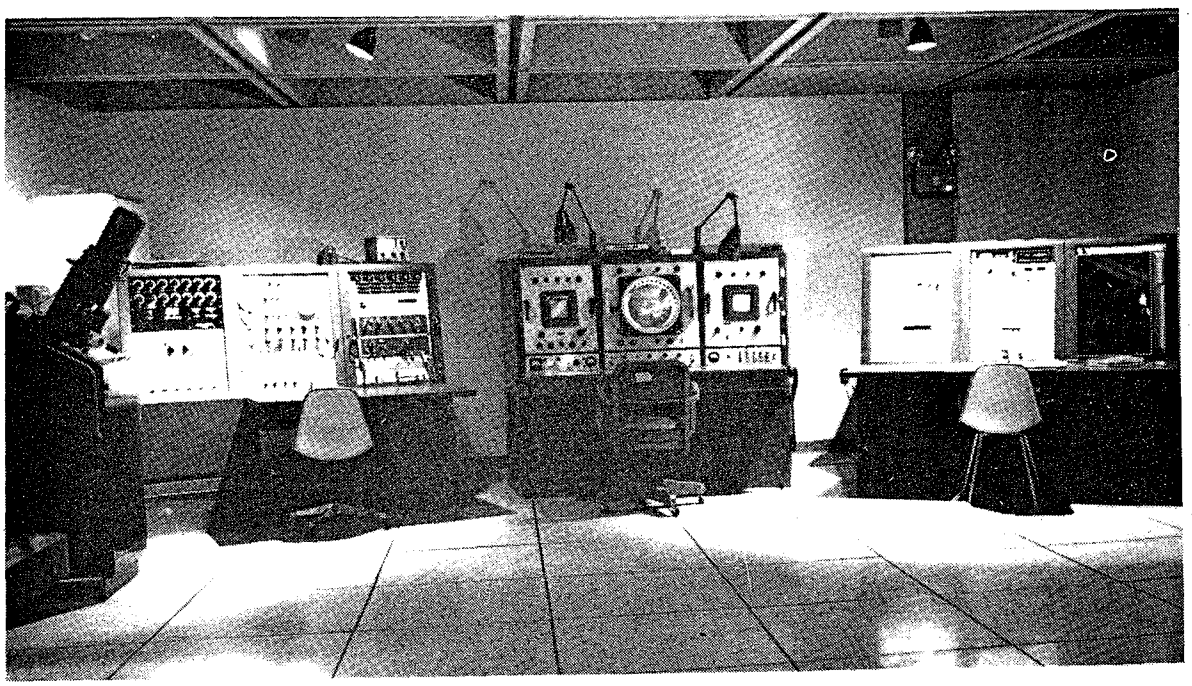

WSR-57 RADAR

# OBJECTIVES AND ACCOMPLISHMENTS OF THE NSSL 1975 SPRING PROGRAM

## PART I

## OBSERVATIONAL PROGRAM

K. Wilk, K. Gray, and C. Clark

National Severe Storms Laboratory
Norman, Oklahoma
July 1976

# PREFACE

The National Severe Storms Laboratory seeks to understand processes that create and sustain thunderstorms and their manifestations, including hail, heavy rain, lightning, and tornadoes, and to develop improved techniques for storm observation and prediction. Toward these ends NSSL has a severe storm observational program conducted annually during spring when storm activity tends to be most frequent and intense. Several kinds of standard measurements are used for surface and upper air measurements that provide support for meteorological sampling by Doppler radars, an instrumented tower, aircraft, and mobile photographic teams. While thunderstorm and slightly larger scales are emphasized, the NSSL data also provide knowledge of the synoptic setting that leads to severe storm formation. Within the customary fiscal and personnel constraints, configuration and method of operation are determined by research requirements of investigating scientists. A description of each year's Spring Program is summarized as an internal NSSL report.

The WSR-57 surveillance radar and the meteorological networks operate almost continuously for 30 to 90 days and their data are archived for later study. The other data sources mentioned operate for various intervals within the main observing period. There are usually about ten severe storm days and one or two tornadic storms during data collection. Although major NSSL interest focuses on the tornadic thunderstorm, less intense storms are also studied by a wide community of scientists both within and without the Laboratory. There are usually four to eight cases of interesting storms that cannot be reviewed in depth prior to the next annual data collection program. After a decade of operation, we have data sets from many severe storm cases archived. Therefore, future investigations will emphasize new probes to enhance synthesis of data on kinematic and dynamic processes inferred from the multiple Doppler and aircraft measurements. Consideration of new concepts and observing techniques may benefit from the perspective provided by the data sets illustrated here.

Most of the line illustrations in this report were computer-plotted as part of routine data processing by NSSL's CDP section. The radar photographs are available on 35 mm roll film, and the digital data on seven track, 556 bpi tapes. Subsynoptic data from the sixteen NSSL surface stations can be obtained from the National Space Science Data Center.

Ken Wilk
Kathryn Gray
Charles Clark

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## INTRODUCTION

The severe storm observational program in 1975 was reduced substantially from that of 1974. The next extensive program is planned for 1976. The reduction in 1975 was due in part to scheduling of major engineering changes in the Doppler signal processing, and in part to limitations of funds and staff. However, within these restrictions, the scope of the program was broad, with participation of scientists from NCAR, University of Wyoming, University of Oklahoma, and the Air Force Research and Development Command.

The program began with an intense 30-day quality control test, primarily concerned with the Doppler radars. The results are summarized in Part II. The routine severe storm surveillance program conducted between May 15 and June 15 is summarized in the following sections.

There were four clusters of observational activities (fig. 1). The Dual-Doppler Program (I) was given highest priority--to widen and test quality control procedures, and further develop hardware and software for improved real time displays. Program II sought to extend Doppler and aircraft measurements of turbulence and severe storm circulations. Program III mixed subprograms in storm surveillance and documentation (WSR-57 radar, rawinsonde, and cloud photography) with first attempts at "nowcasting" using hourly surface, 30-minute satellite, and continuous radar observations to make 1-2 hour predictions. Program IV provided benchmark data to describe boundary layer conditions during severe storms.

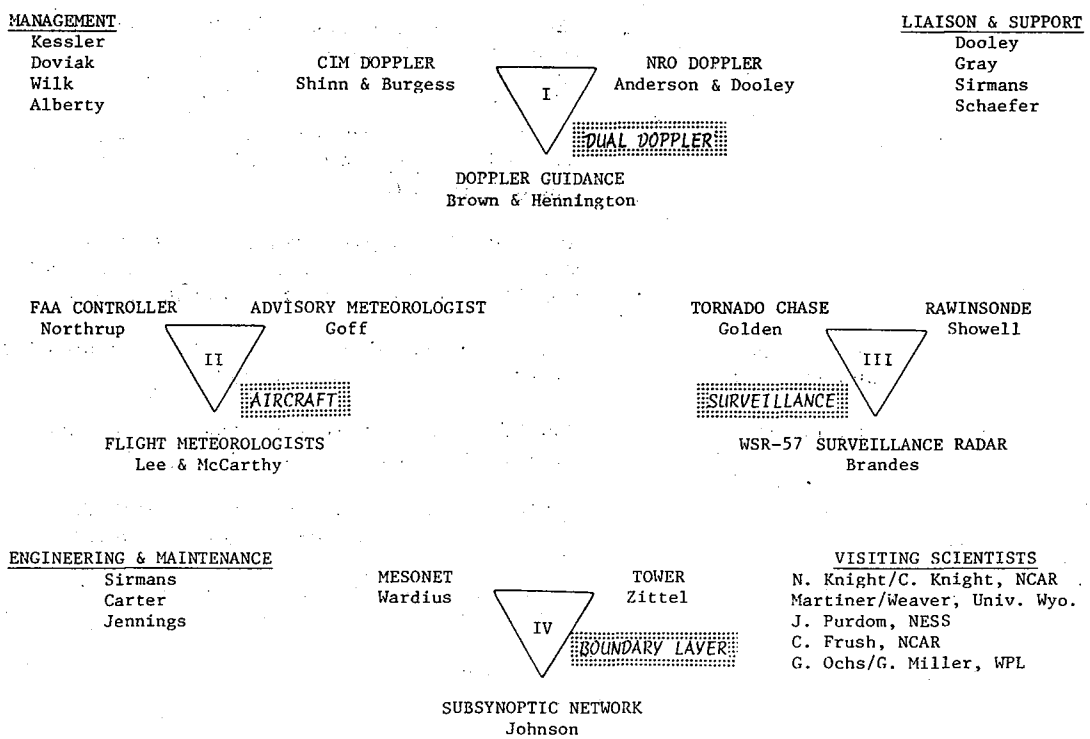



Figure 1. Observational activities.

Most of the project scientists participated in data collection with Operations staff and helped define operating procedures. Unless severe weather was evident, operations were restricted to normal working hours, with evening and weekend storms covered on a catch-as-catch-can basis.

Individual project goals (fig. 2) determined sampling rates and radar control configurations, including choice of high or low pulse repetition frequency, dual-Doppler scanning, scope photography, and digital recording.

PROJECT GOALS

| | INVESTIGATORS | EXPERIMENTS |
|---|---|---|
| 1. | Brandes and Sirmans | WSR-57 radar: *Wet radome effect on rainfall measurements.* |
| 2. | Brandes and Sirmans | WSR-57 radar: *Effect of sampling interval on precipitation measurements.* |
| 3. | Brandes and Sirmans | NRO and CIM Doppler radar data: *Effect of velocity variance on precipitation measurements.* |
| 4. | Ray | NRO Doppler radar: *High PRF and tornado detection.* |
| 5. | Brown, Davies-Jones McCarthy, and Ray | NRO and CIM Doppler radars, WSR-57 radar, chase teams, aircraft and radiosonde: *3-D modeling.* |
| 6. | Burgess | NRO and CIM Dopplers: *Study of vortex signatures as shown on reflectivity and PPP displays.* |
| 7. | Kessler | WSR-57 radar: *Demonstration of immediate analysis of raingage and radar data using the Brandes technique.* |
| 8. | Lee | NRO and CIM Doppler radars: *Correlation of aircraft wind and measured turbulence with Doppler wind and variance measurements.* |
| 9. | Golden, Davies-Jones, Purcell, and Doswell | WSR-57 and Doppler radars: *Film documentation of tornadoes and damage surveys.* |
| 10. | Schaefer and Lemon | WSR-57 radar, satellite, rawinsonde, and Service A data: *Severe storm prediction.* |
| 11. | Dooley, Showell and Zittel | Optical anemometers and mesonetwork data: *Direct measurement of surface convergence.* |
| 12. | Walker and Ray | Acoustic radar and WKY tower data: *Quantitative measurements with the acoustic radar.* |
| 13. | Nelson | Radar and Volunteer Observers network: *Hail Studies* |
| 14. | WPL; NCAR; Wyoming [Ochs, Young, Frush, C. Knight, N. Knight, and Martener | WSR-57 and Doppler radars; *Optical anemometer; Project Dustorm; Storm Chase.* |

Figure 2. Project goals.

## SECTION 1

### Modus Operandi

A Central Control Facility was established in 1974 in the Norman Doppler Building (Barnes et al., 1974). During 1975, controllers for chase and rawinsonde projects were returned to the WSR-57 radar room in the main building to relieve congestion in the Doppler building and to separate communications. This year, "real time" discussions to coordinate dual-Doppler and aircraft probing were not mixed with "delayed time" operations involving guidance messages to chase teams and rawinsonde flights. By reducing cross talk and clustering the projects, it was hoped that fewer staff would be required and the operation would be more efficient.

This was only partially successful. While several of the experiments completed data collection independently, the chase teams were not always adequately supported in their statewide pursuit of severe storms.

For example, some data were lost on major storms on June 6 and June 13, because of cessation of operations between 1700 and 1900 CST. Also, ad hoc arrangements did not provide satisfactory radar coverage during the evenings and on weekends. Improvements in short range prediction are needed to keep the operational teams on site when new storm development is eminent.

The deploying of radar, rawinsonde, and chase teams requires prediction of the likelihood of thunderstorms and prediction of generally when and where (i.e., occurrence in the dual-Doppler area, within driving distance of the chase vehicles, and occurrence before sunset for aircraft probing). Each morning, a "convective outlook" was prepared to indicate presence and motion of the fronts and upper level short waves and to specify "standby" status for the day. The sequence of activities which followed on storm days is illustrated in Figure 3. On "no-standby" days, the radar crews returned to work on the new Pulse-Pair processors or to run quality control checks and fine tune the radar systems. On "standby" days, all radars were calibrated and made ready for data collection. Beginning at noon, the "nowcaster" used 30 min satellite and continuous radar observations to supplement hourly surface analysis. During the afternoon and early evening, he prepared frequent advisories for dissemination to the project teams.

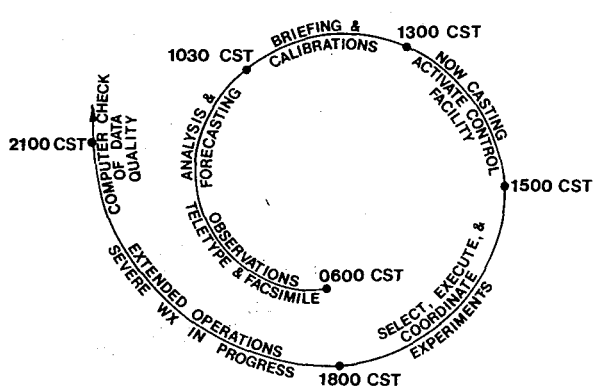



Figure 3. 1975 Operations Clock.

The three radar sites were linked by lease-line telephone for voice communication. A telewriter system was used as back-up and for leaving messages. A radio communication system, using a repeater transceiver on the WKY tower, linked the Central Control Facility, chase cars, rawinsonde sites, and WSR-57 radar room.

The 1975 upper air network was limited to two rawinsonde stations at Tinker AFB and Fort Sill, Oklahoma. A subsynoptic network of 16 surface stations (fig. 4) was operated to supplement the hourly NWS observations. Examples of these data with streamline analysis are shown later in the discussions of the major storms.

Closed circuit television was used to relay satellite pictures, surface analysis and nowcasts from the main building to the Central Control Facility. A tower-mounted television sky camera, remotely controlled from the radar room, provided real time (and video taped) data on distant cloud tops visible from the Laboratory.

Digital data sets were scanned and archived by the Laboratory's Computer Processing Group. The Operations Group screened and archived analog and film data from the surface networks, WSR-57 radar, and the WKY tower. Section 3 contains lists of data now available for study, and material relative to the format of the data.

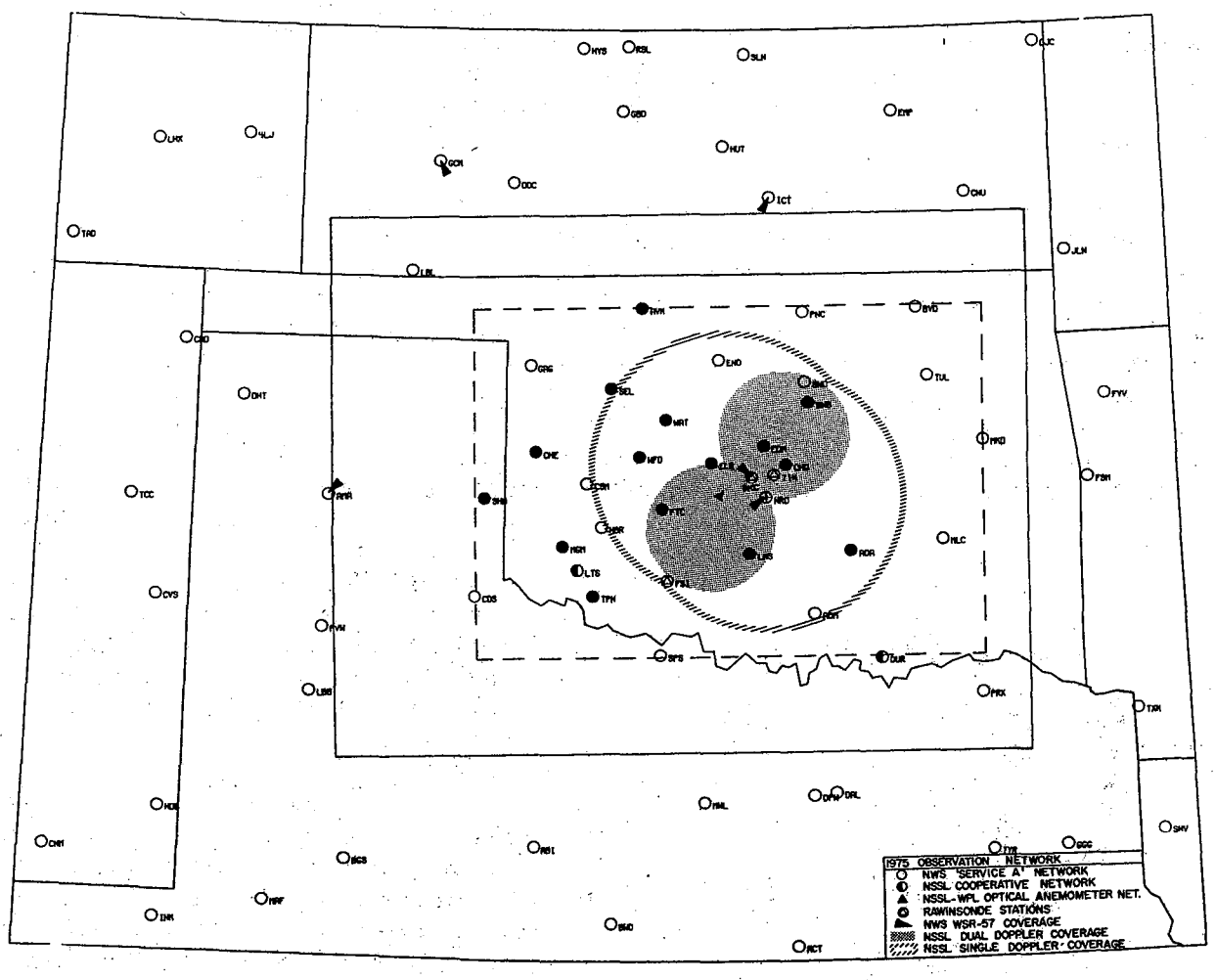



Figure 4. 1975 Observational Network

## SECTION 2

### Synopsis of the Major Storms

In documenting activities of the 1974 program, Barnes (op cit) showed daily synoptic analyses and WSR-57 scope displays. In addition to these, there are numerous other cases documented in detail (Barnes, 1970; Vlcek, 1973; Lemon, 1976; Brown, 1973) and little new information could be added by showing similar records for 1975. Instead, three cases are illustrated in this report to exemplify situations with varying degrees of difficulty to "nowcast". Similar situations occur each year, sometimes resulting in excessive overtime, loss of data, and "household" hardships. Fortunately, the most severe situations are usually predicted by forecasters at NSSFC, and handled very well by NSSL forecasters on an hour-by-hour basis.

The three cases chosen for graphic review in this report are May 26, June 6, and June 13. On May 26, the first NSSL computerized display of mean velocity was recorded showing a mesocyclone signature in real time (Burgess, 1976). The Doppler data were supplemented with measurements from the University of Wyoming mobile weather station (Martner, 1975) and the NCAR aircraft. As shown in the following illustrations, the storm was an isolated cell, developing in an area of weak cyclogenesis at the time of maximum surface heating.

The second storm, June 6, was a "typical" evening mid-western squall line which produced a classical gust front (Goff, 1975). Surface wind speeds reached 46 m $s^{-1}$ at Edmond, Oklahoma, a few km north of the NSSL tall tower facility. No Doppler data were collected because of the extensive multiple trip return, and because the development of the line occurred in late evening after the cessation of normal operations.

The final case illustrated was a major tornado occurrence at Stillwater, Oklahoma, about 110 km northeast of NSSL. Dual-Doppler radar, aircraft, and WSR-57 three-dimensional data were obtained while several people in Stillwater were photographing the funnel cloud.

Data inquiries and requests should be submitted in writing to:

Mrs. Kathryn C. Gray
Computer and Data Processing
National Severe Storms Laboratory
1313 Halley Circle
Norman, Oklahoma 73069

Date: 26 May 1975

. . . . . Forecast (1100 - Sunset) . . . . . [X] Standby [ ] No Standby

Discussion:

Yesterday - Went as forecast with even less clouds than called for.

Today - 9:00 a.m. front Harrison - Altus - Clovis. Wave formed by 10:00 a.m. at Altus with front to south past Mineral Wells - Midland. Air mass south of front quite unstable. 500 mb trying to go zonal with weak "wiggles" present. Expect early afternoon show in south and southeast Oklahoma.

---

. . . . Outlook for Tomorrow . . . . [ ] Standby [X] No Standby

Discussion:

Indications are that front to settle south of Red River during night leaving unseasonable cool stable air mass.

Joseph T. Schaefer

Figure 5. NSSL Operational Forecast, issued at 1100 CST each day.

## CASE I

### May 26, 1975

The storm developed on a frontal wave crest 120 km southeast of NSSL. As indicated in the Forecast and Nowcast, activity was anticipated and WSR-57 radar data collection began prior to time of first echo. The satellite picture at 1545 CST shows the storm developing southwest of NSSL, just beyond the range of the Doppler radar at Cimarron. The Norman Doppler radar was within sampling range for a brief period and recorded the first real time display of the mean velocity and spectral width values at 1538 CST.

The reflectivity and Doppler velocity fields indicate the storm contained hail and cyclonic circulation aloft. The University of Wyoming Chase Team observed heavy rain and hail and a weakly developed wall cloud, however, a telephone survey of the 100 $km^{-2}$ area failed to locate wind damage or observations of funnel clouds. A "fly-by" probe to the southwest of the storm was made by the NCAR aircraft during the period of rapid growth, and the University of Wyoming staff later collected drop size data at 1600 CST further south in the same storm (Martner, op cit).

Some significant aspects of the data sets are mentioned in the figure captions.

*NOWCAST FOR 26 MAY 1975*

*Based on 1124 CST data. Appears that wave is around Rush Springs, Lindsey area with front extending to SW and discontinuity or front (unclear which) to ESE. Warm unstable air mass to south with convergence along discontinuities should give rise to TRW. Lack of upper air support is only significant--but serious--drawback. No short waves evident on satellite pictures except one to east in Arkansas. Possible first echo experiment (outside dual-Doppler network) but will have to result from surface forcing (not upper level lift).*

*1200 CST data. Actual front is difficult to differentiate. May be radar detectable thin line (dashed on map analysis) or wave discontinuity system to south. (Line of cumulus along ESE portion of discontinuity is quite evident on 1123 CST satellite photo.) Greatest chance for TCU and TRW growth will occur when thin line overtakes wave in 3-4 hours near or north of ADM.*

*1300 CST data. Now appears that thin line is front and early morning TRW outflow produced discontinuity (along which TCU are presently seen in satellite pictures) extends ESE from wave. Best TRW chance will be near wave-front-outflow intersection in about 2 hours with additional surface heating since synoptic surface forcing is weak and upper support is lacking.*

*1400 CST data. Satellite and radar development have begun to occur rapidly on outflow boundary. This should persist and juncture between front and boundary looks favorable for further development. With strong instability these cells look good for large hail.*

*1500 CST data. Satellite data shows some weakening or "breaking up" of boundary W of strong cell S of ADH. However, front still in that area and generation of another meso system to provide forcing must be considered possible. Satellite pictures provided excellent information on overall situation and high potential region but neither satellite nor surface data indicated TCU enhancement before radar detected first echo.*

*Leslie R. Lemon*

Figure 6. NSSL Operational Nowcast, issued hourly beginning at 1100 CST on standby days.

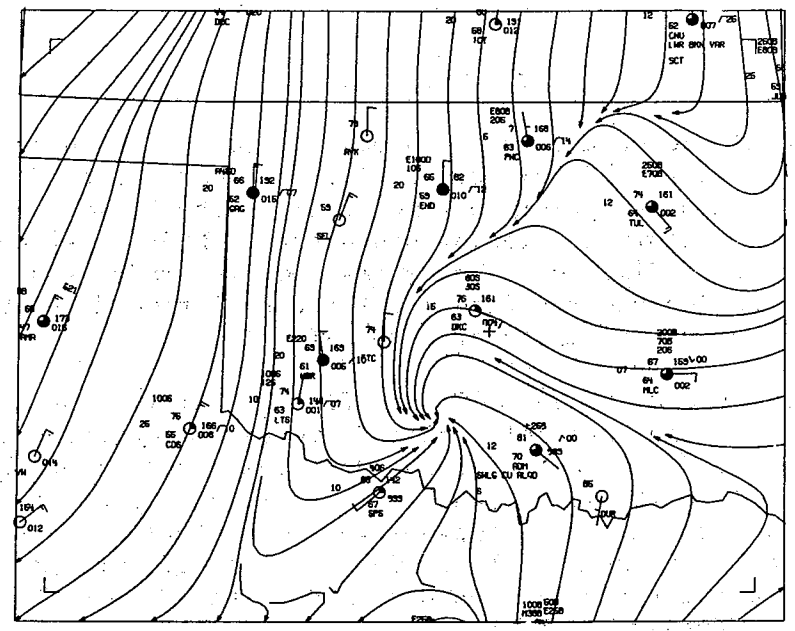


Figure 7. Surface map time 1200 CST. Boundary layer convergence over south-central Oklahoma three hours prior to development of severe thunderstorm. Line of convergence extending northwest marks a southward moving cold front, which was "seeded" with chaff at 1300 CST.

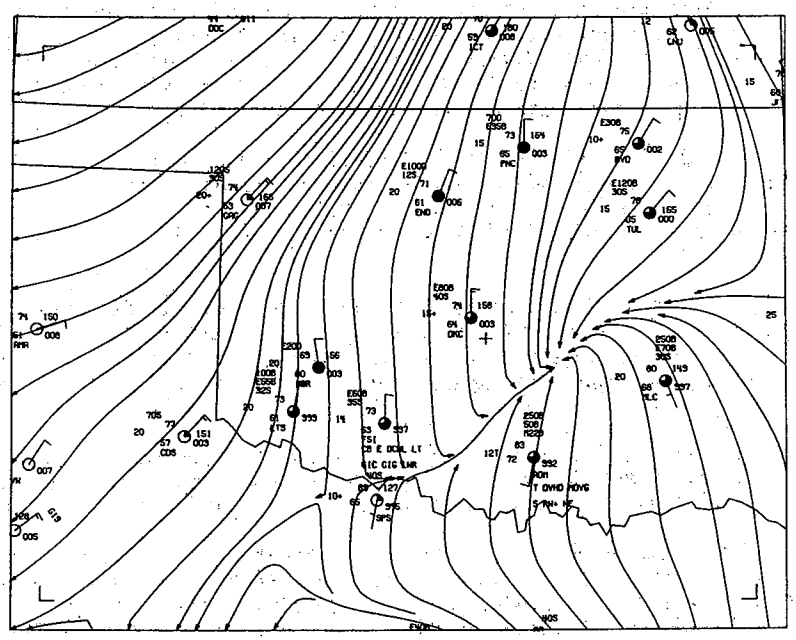
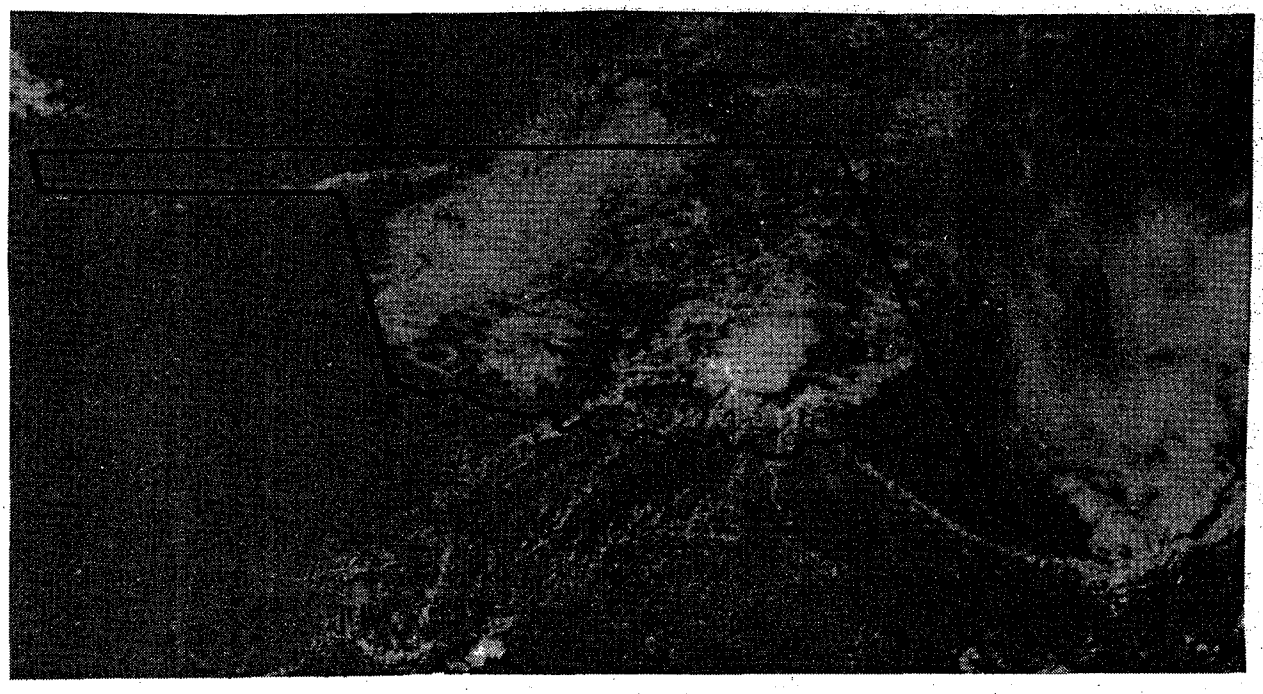


Figure 8. Surface map time 1600 CST. Boundary layer convergence during severe storm. The line of convergence with the cold front apparently merged with the subsynoptic scale cyclone (or is no longer resolvable), which has moved northeast.



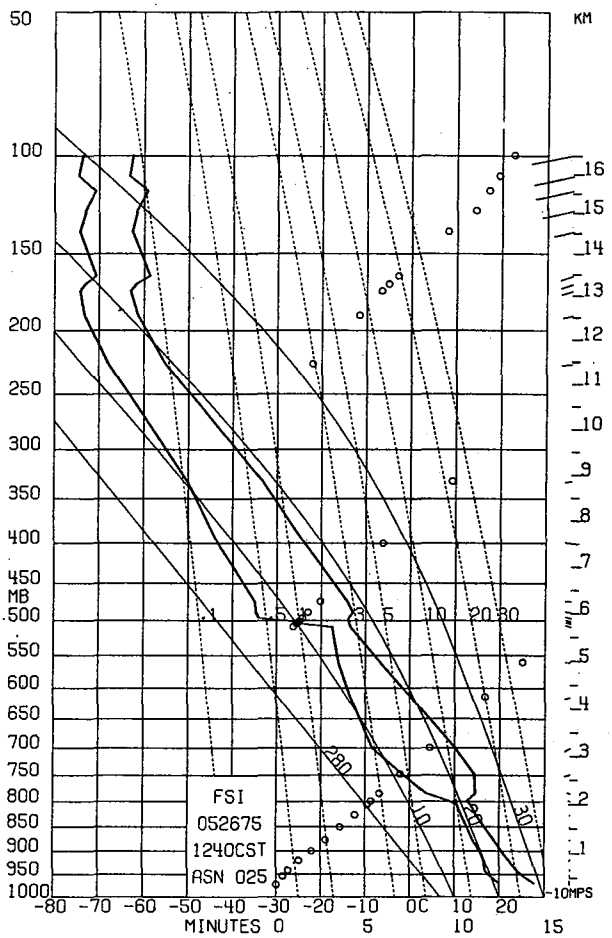



Figure 9. (above) Satellite photograph taken at 1545 CST, 26 May 1975, showing thunderstorm development on wave crest in south-central Oklahoma. The warm air boundary extending into east Texas was created by the southward moving nighttime squall line now dissipating over western Louisiana.

Figure 10. (left) Sounding taken at Fort Sill, Oklahoma, 130 km west, and approximately one hour before the development of the storm.

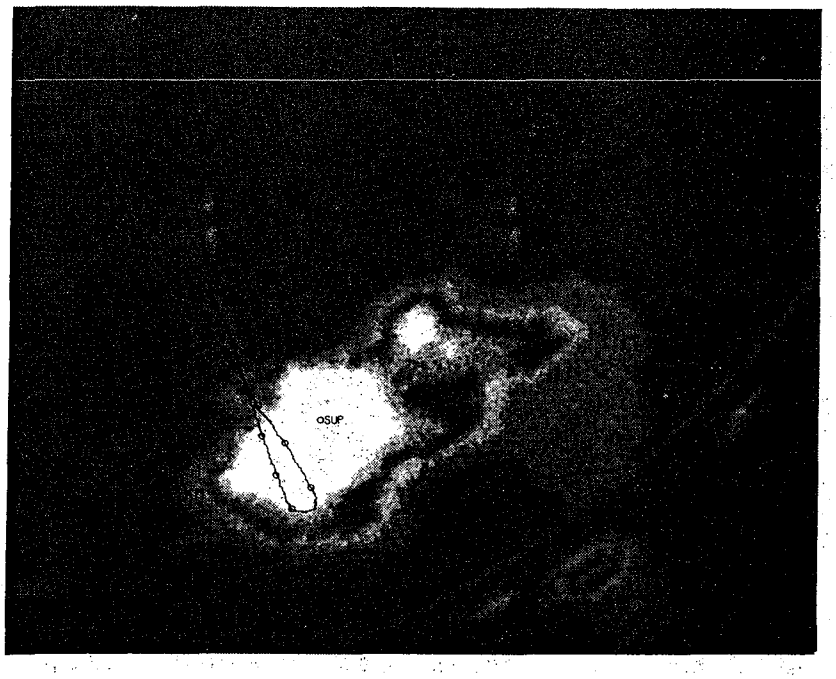
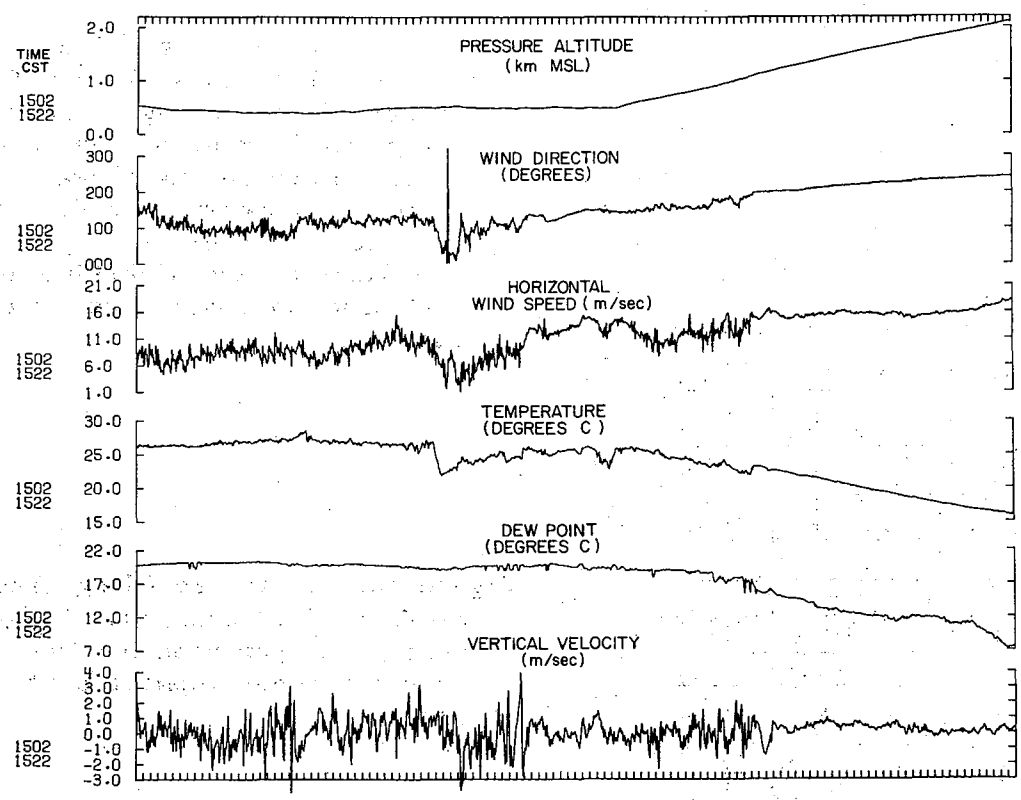



Figure 11. Track of NCAR aircraft taken to record data shown below. The University of Wyoming mobile weather station was southeast of Sulphur (SUP) at the time. The small cancellation north of SUP is coincident with reports of marble size hail.



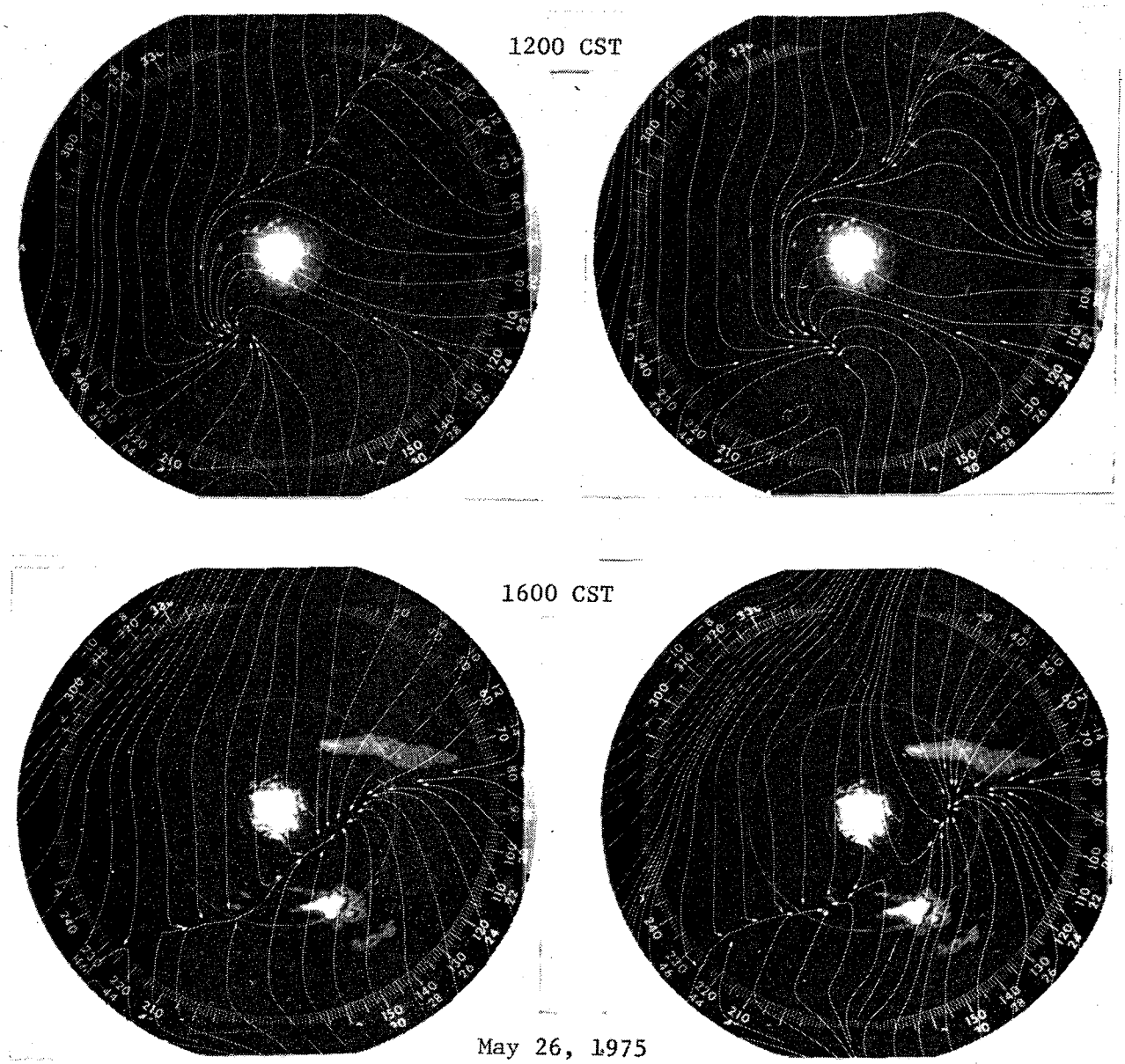



Figure 12. The subsynoptic trajectory analyses are shown superimposed on the WSR-57 radar displays. In each case, the left photograph is the wind pattern derived using the technique developed by Barnes (1974), and the right photograph shows the Barnes output analyzed with a pressure constraint developed by Sasaki (1973). In most of these cases the differences in the convergence patterns are second order. However, the effect on magnitudes of moisture convergence may be more significant.

Figure 13. (right) Comparison between WSR-57 and NRO Doppler radar intensity measurements made simultaneously in the Storm of May 26, at 1535 CST, at 4° antenna tilt.

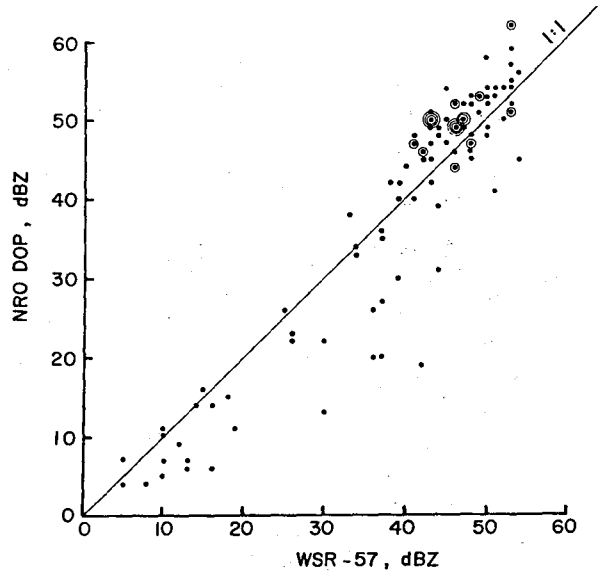
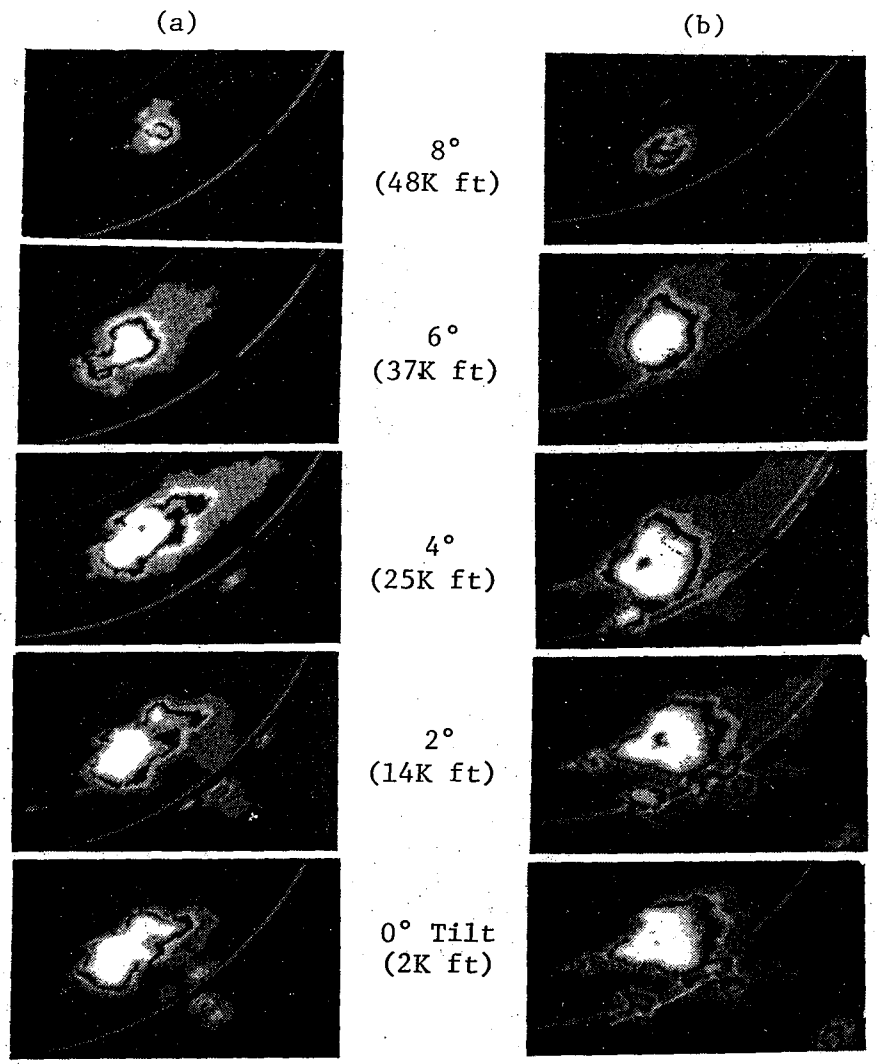



Figure 14. (below) WSR-57 radar tilt sequences showing vertical profile of storm reflectivity patterns at 1515 CST and 1540 CST.



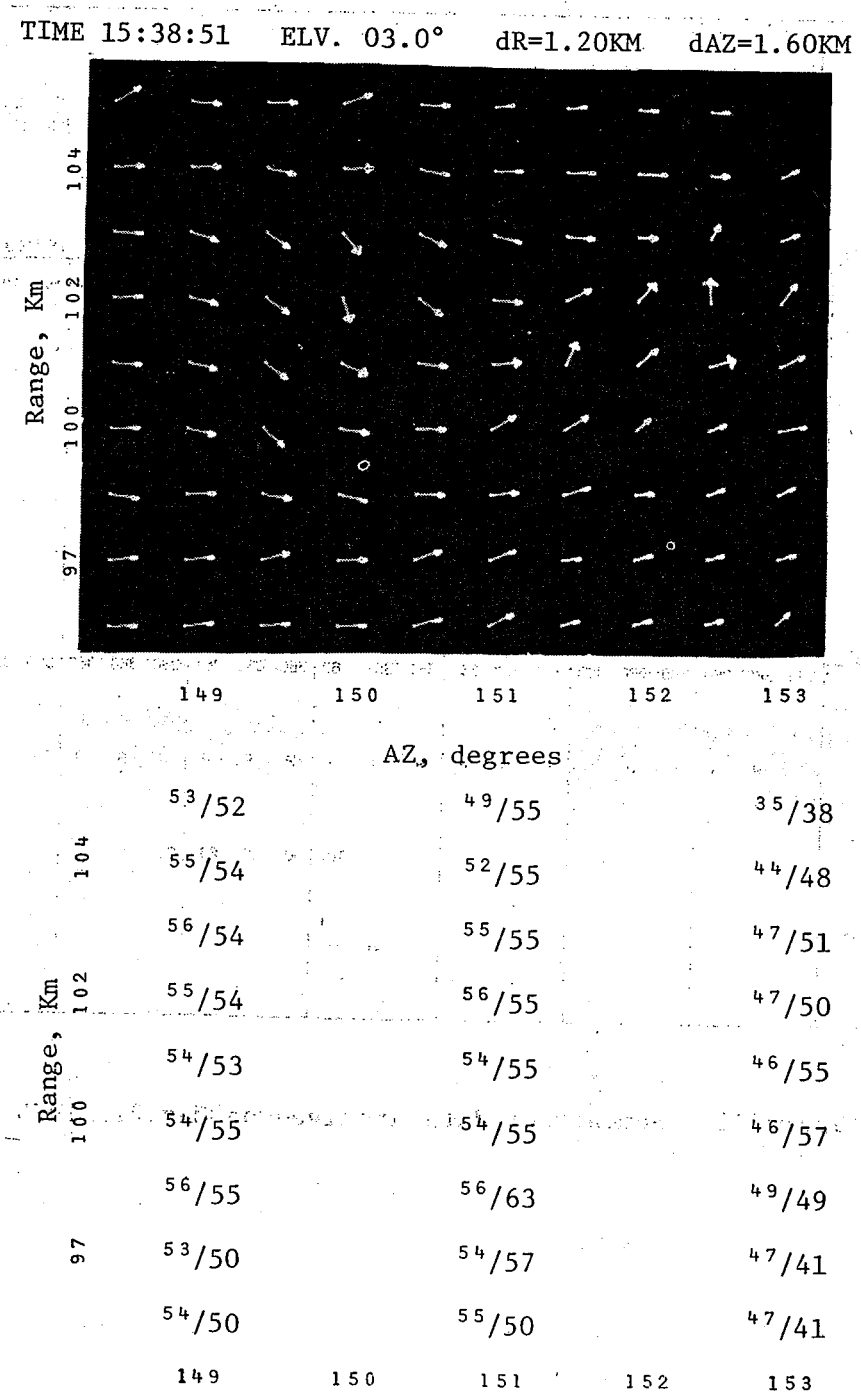



Figure 15. (top) Example of NSSL computerized, multimoment display of Doppler mean wind speeds. Rotation of arrows from right (0 velocity reference is pointing to right) indicates magnitude of wind, i.e., counterclockwise is away from the radar and clockwise is toward the radar. Full rotation to the left is 34 m $s^{-1}$. The spread of the arrowhead indicates spectral width. For interpretation of cyclone signature see Burgess (1976). (bottom) WSR-57 (small digits) and NRO Doppler (large digits) radar reflectivities (dBZ) for locations above, measured at 0 and 3 degree antenna tilts, respectively.

# STORM DATA SUMMARY
## DATE 052675

| | HOUR 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WSR-57<br>0 DEGREE SECTORS COLLECTED<br>/ = TILTS COLLECTED | | | | | | | | 4 | 14/ | 11/ | 14/ | 8/ | 4/ | | 15/ | 32/ | 28/ | 28/ | 15/ | 12/ | | | | |
| DOP NRO<br>MINUTES OF DIGITAL DATA | | | | | | | | | | | | 6 | | 5 | 4 | 16 | 7 | | | | | | | |
| DOP CIM<br>MINUTES OF DIGITAL DATA | | | | | | | | | | | 1 | | | 5 | 5 | | | | | | | | | |
| RAOB<br>RELEASES | | | | | | | | | | | | | 1 | | | | | | | | | | | |
| WKY TOWER<br>OBSERVATIONS PER HOUR | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 339 | 364 | 361 | 361 | 362 | 360 | 363 | 361 | 360 | 360 | 360 | 360 | 361 | 360 | 361 | 360 | 360 |
| MESONET<br>A = ANALOG<br>D = DIGITAL<br>S = TO BE DIGITIZED<br>AD= A AND SOME D | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A |
| AIRCRAFT<br>MINUTES OF DIGITAL DATA NCAR QUEEN AIR | | | | | | | | | | | | 18 | 60 | 44 | 23 | 22 | | | | | | | | |
| AIRCRAFT<br>MINUTES OF DIGITAL DATA AIR FORCE F4C | | | | | | | | | | | 20 | 21 | | | | | | | | | | | | |

Figure 16. Summary of data archived on May 26, 1975.

## CASE II

### June 6, 1975

Storms in Kansas were large and severe most of the day. Individual storm movement was southeastward across northern Oklahoma until about 2100 CST, when an organized squall line moved rapidly southward into central Oklahoma and produced a major gust front, which preceded slightly ahead of the precipitation. Severe weather was first reported in northwest Oklahoma (Woods County) about 1700 CST. One of the three tornadoes sighted was rotating anticyclonically (documented on film). Heavy wind damage occurred 20 km north of Oklahoma City. Scattered hail and high winds were reported in 20 counties in northern and eastern Oklahoma (Storm Data, 1975).

The surface maps, WSR-57 radar display, and satellite photograph show the very moist air converging in the areas of thunderstorm development, and the resulting squall line. The WKY tower data contained peak gusts of 35 m $s^{-1}$. Multiple trip signals prevented the collection of Doppler radar data.

*NOWCAST FOR 6 JUNE 1975*

*Based on 0900 CST data. Short wave lifting is most apparent in mid and high clouds over central and northwest Kansas, extreme northeast Colorado and southwest Nebraska and is expected to track east-southeast or southeast giving strongest activity in Kansas, north-central and northeast Oklahoma.*

*1200 CST data. Very strong TRW have developed in northeast Colorado, southwest Nebraska and northwest Kansas with line of CB and TCU southward to near LHX Colorado. Two other TRW have developed near CAO New Mexico. These two TRW indicate lifting is occurring further south than previously indicated by SMS and forecast progs. This indicates that northwest Oklahoma, central and southeast may eventually be involved in TRW activity during late afternoon and night.*

*1400 CST data. Very strong activity has developed in southwest and south-central Kansas with a field of TCU and CU southeastward. Activity has also developed in west Texas panhandle. Indications are that activity (strong to severe) will move into area around 1900 CST.*

*Leslie R. Lemon*

Figure 17. NSSL Operational Nowcast, beginning at 0900 CST on June 6, 1975.

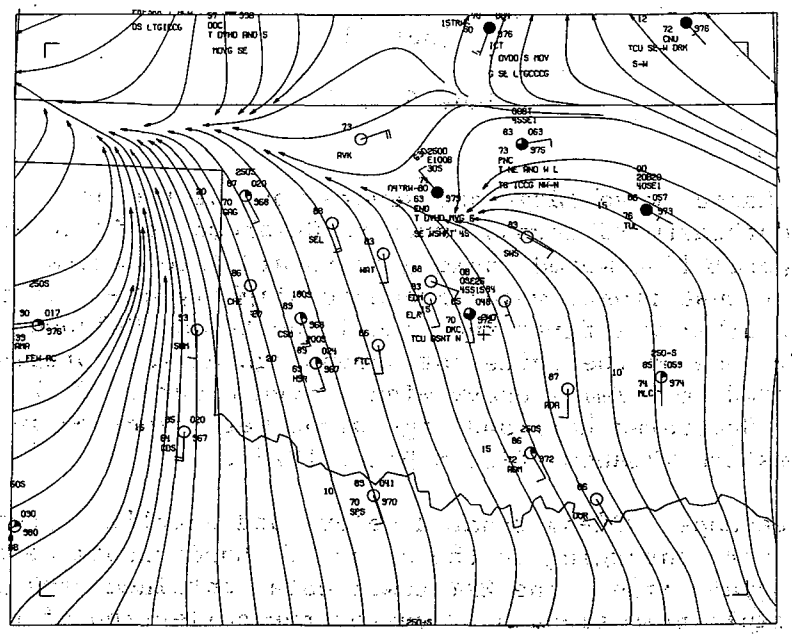


Figure 18. Surface map time 1900 CST. Boundary layer trajectories during intensification of squall line. Note the extremely high dew-point values in the air flow arriving in north-central Oklahoma from eastern Texas.

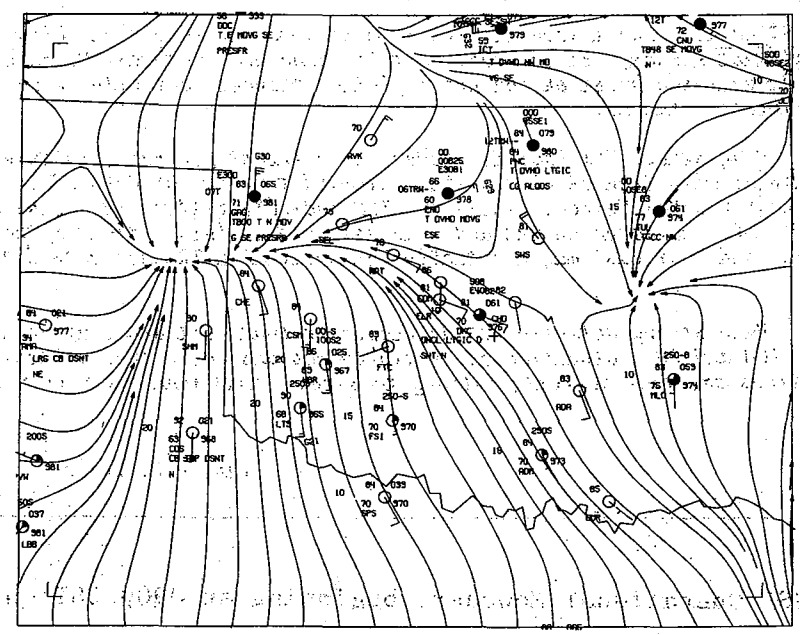


Figure 19. Surface map time 2000 CST. Boundary layer trajectories as the squall line accelerates southward and develops westward. A radar thin line appeared at 2130 CST, and moved southward at 21 m $s^{-1}$ ahead of the precipitation (see fig. 22.)

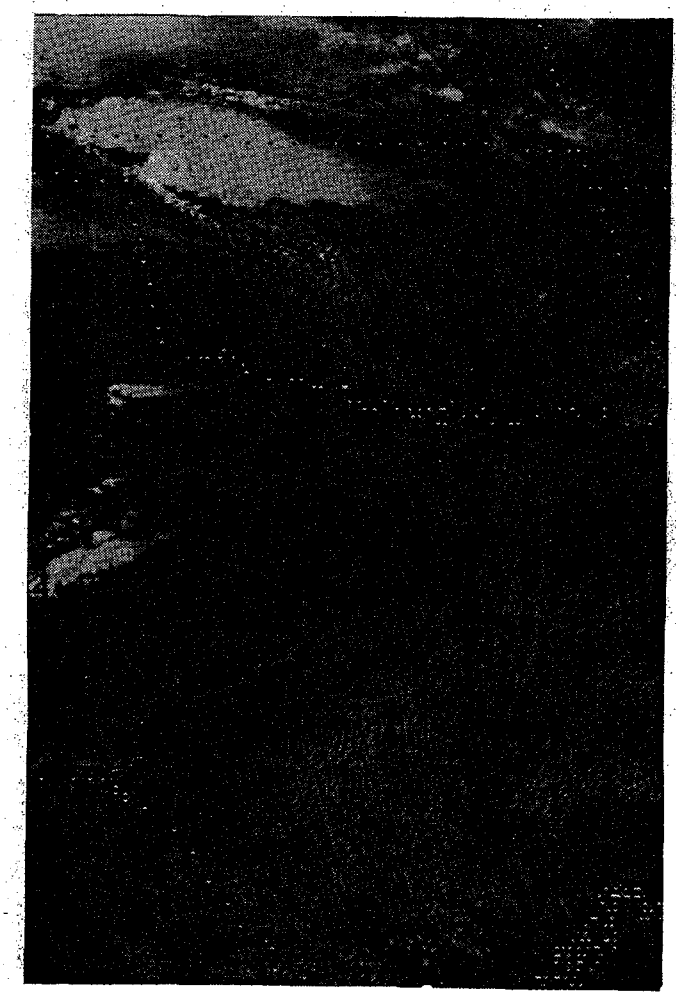


Figure 20. Satellite photograph at 1545 CST, June 6 showing advection of Gulf moisture northward to feed expanding thunderstorm activity over northwest Oklahoma.

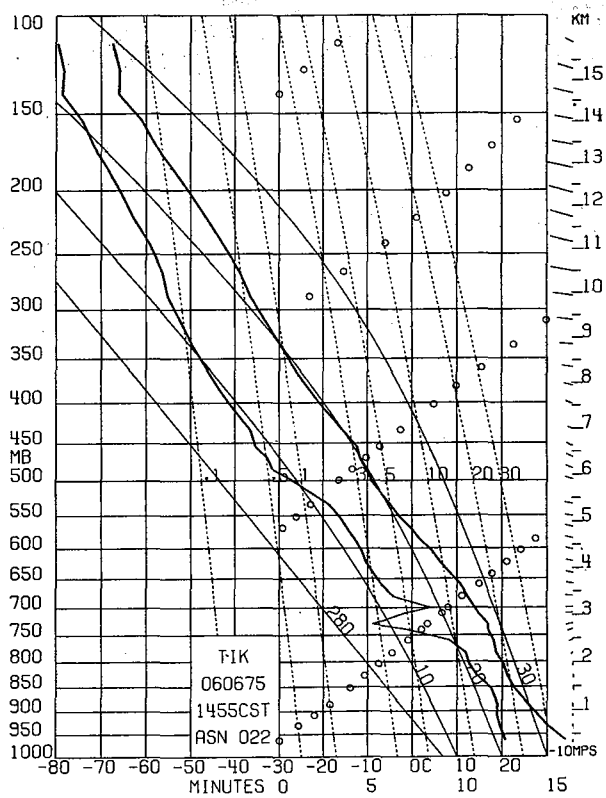



Figure 21. Temperature, moisture, and wind profiles in the conditionally unstable air mass at Oklahoma City. Sounding was made approximately six hours prior to formation of the squall line. Movement and propagation of the line was toward the southeast at 20 m $s^{-1}$, which is 30 degrees to the right of the mean environmental wind at a height (7.5 - 9.5 km) where the speed $\geq$ 20 m $s^{-1}$.

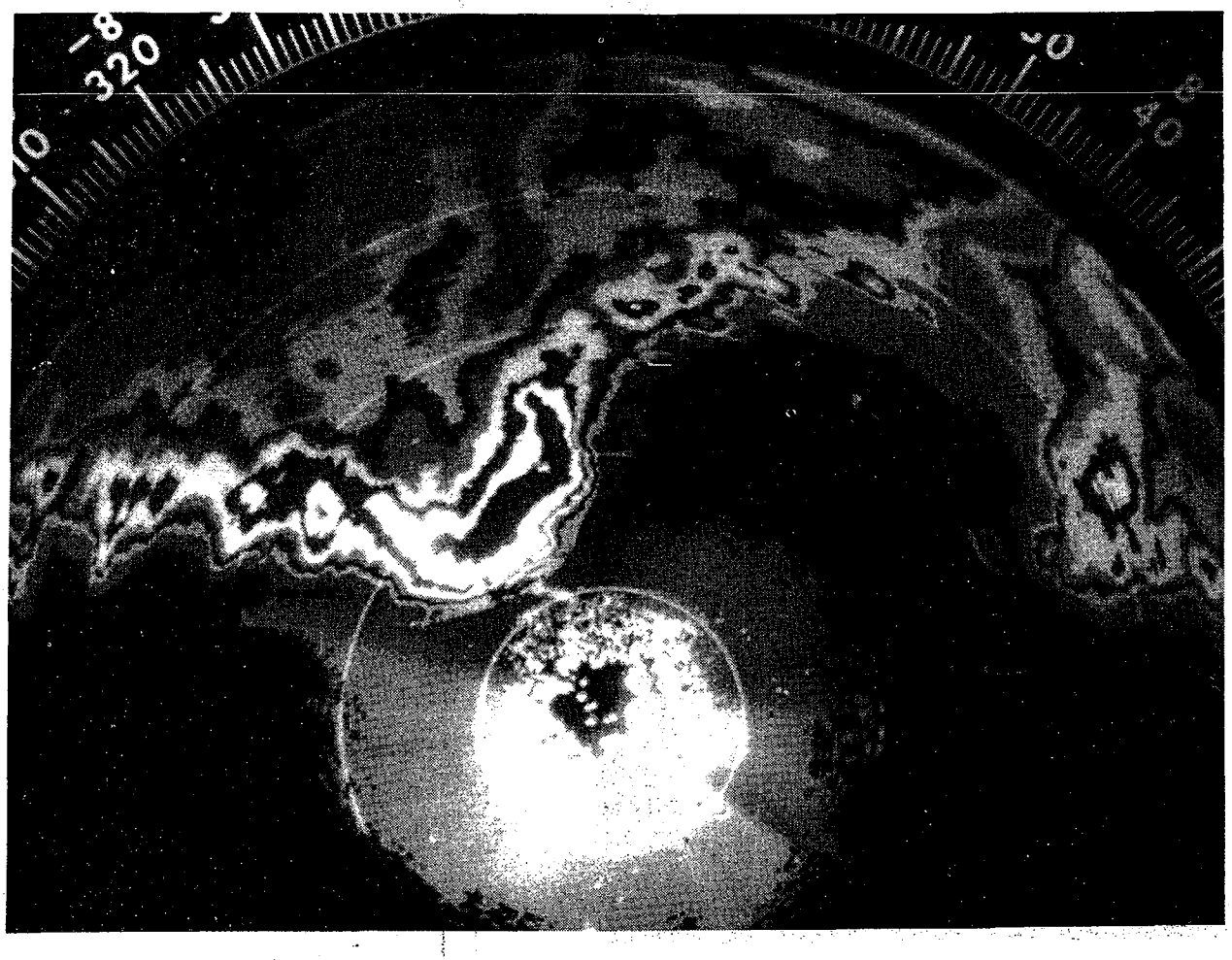



Figure 22. WSR-57 display without range normalization, showing the beginning of the gust front echo as it emerges from the line. It is now 10 minutes, or 16 km from the start of the tower section shown in Figure 23.

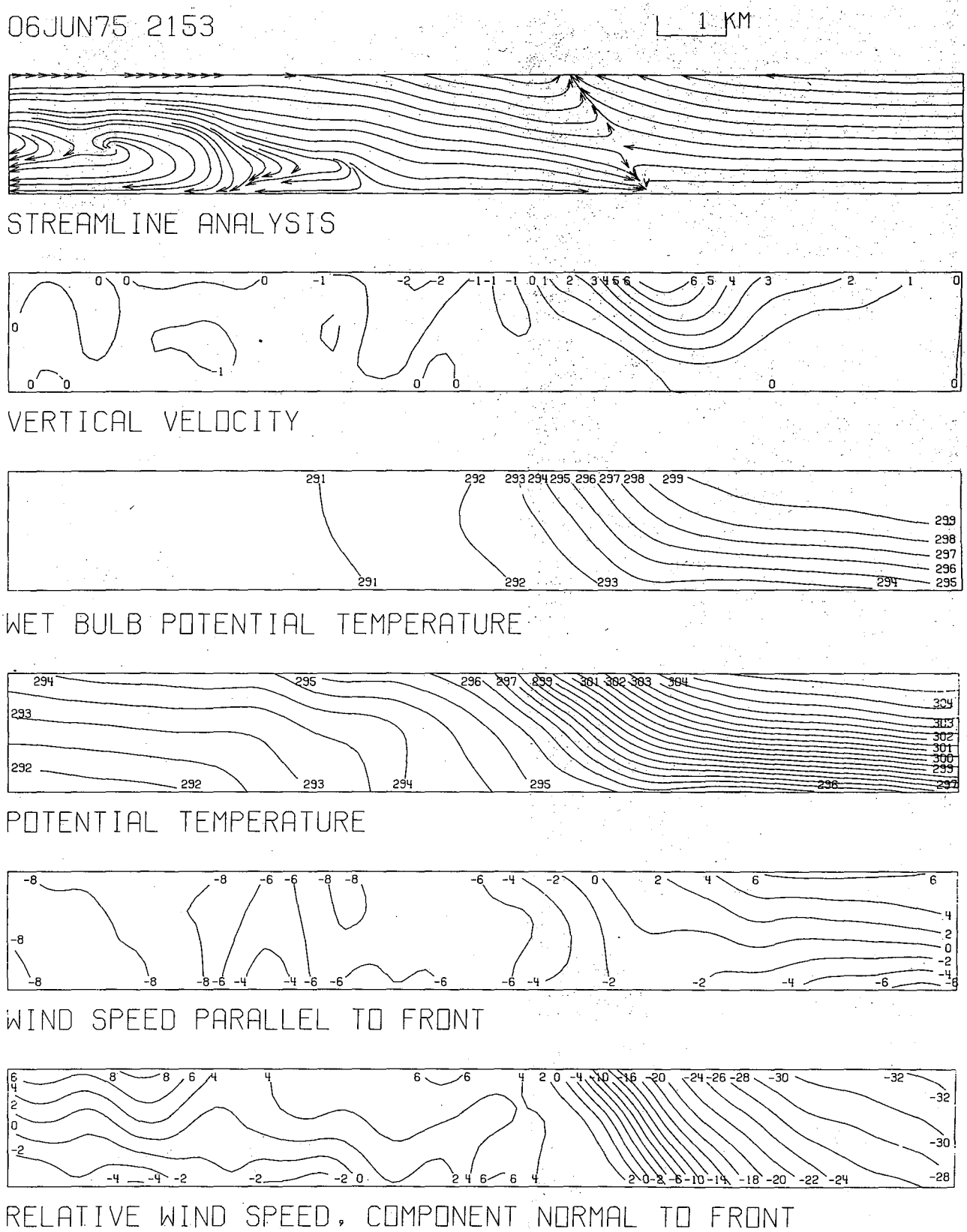
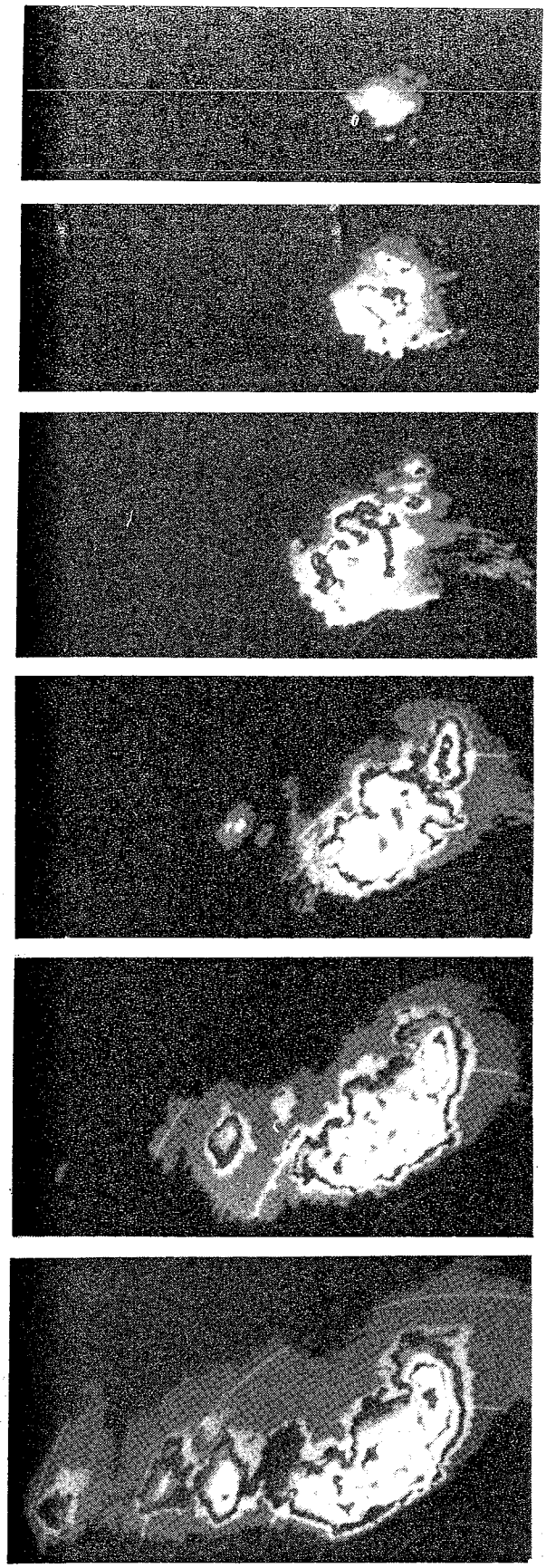



Figure 23. Time (space) section of smoothed 444 m tower data obtained during severe squall line passage, June 6, 1975. (See Goff, op. cit.)



14°
(48K ft)

12°
(42K ft)

10°
(35K ft)

8°
(28K ft)

6°
(21K ft)

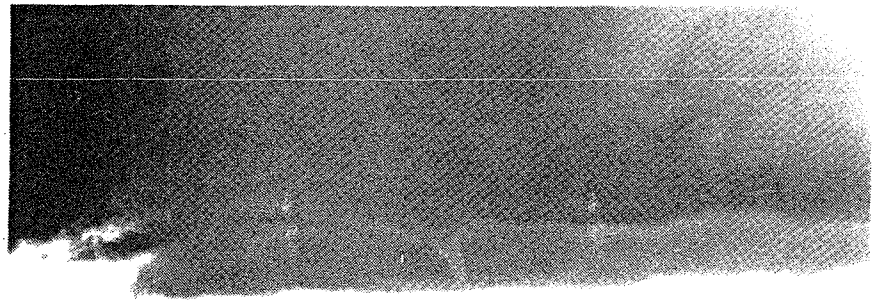
4°
(14K ft)

Figure 24. WSR-57 radar reflectivity profile at time of maximum storm development and origin of gust front.

## STORM DATA SUMMARY
### DATE 060675

| | HOUR 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WSR-57<br>0 DEGREE SECTORS COLLECTED<br>/ = TILTS COLLECTED | | | | | | | | | | | | | | | 5 | 11 | | | | | 16/ | 20/ | 17/ | 14/ |
| DOP NRO<br>MINUTES OF DIGITAL DATA | | | | | | | | | | | | | | | | | | | | | | | | |
| DOP CIM<br>MINUTES OF DIGITAL DATA | | | | | | | | | | | | | | | | | | | | | | | | |
| RAOB<br>RELEASES | | | | | | | | | | | | | | 1 | 1 | | | | | | | | | |
| WKY TOWER<br>OBSERVATIONS PER HOUR | 360 | 360 | 360 | 360 | 359 | 360 | 360 | 360 | 343 | 360 | 360 | 360 | 360 | 359 | 359 | 360 | 360 | 360 | 360 | 359 | 360 | 358 | 88 | |
| MESONET<br>A = ANALOG<br>D = DIGITAL<br>S = TO BE DIGITIZED<br>AD= A AND SOME D | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A |
| AIRCRAFT<br>MINUTES OF DIGITAL DATA — NCAR QUEEN AIR | | | | | | | | | | | | | | 12 | 60 | 35 | | | | | | | | |
| AIRCRAFT<br>MINUTES OF DIGITAL DATA — AIR FORCE F4C | | | | | | | | | | | | | | | | | | | | | | | | |

Figure 25. Summary of data archived on June 6, 1975.



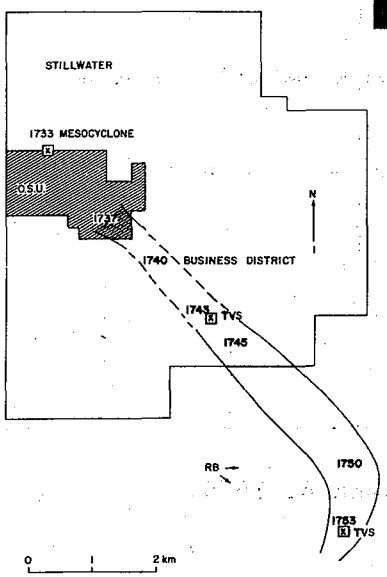
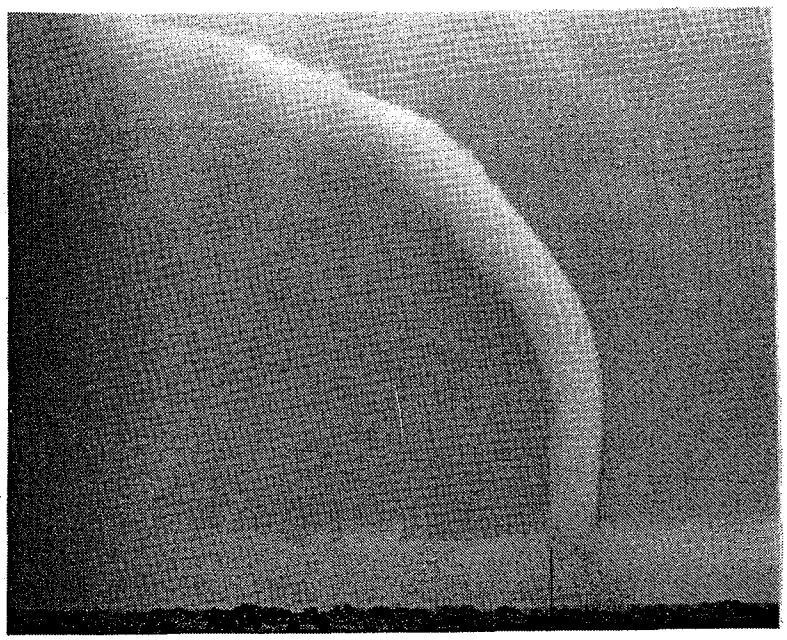



Figure 26. Tornado at Stillwater, Oklahoma, June 13, 1975. (above) Wall cloud and developing tornado at approximately 1737 CST. (below) Tornado at approximately 1753 CST, after destroying trailer park. (left) Damage path and location of Doppler radar vortex signatures (TVS) recorded during the tornado.



## CASE III

### June 13, 1975

On this day, the boundary layer flow over northern Oklahoma was southerly, weakly convergent, with mean level steering winds from the northwest. Scale of the convection, shown by satellite and WSR-57 radar was large--indicative of severe storms. A large tornado occurred at Stillwater at 1737 CST. An excellent radar data set was obtained, which is receiving special attention at NSSL and the University of Oklahoma.

*NOWCAST FOR 13 JUNE 1975*

*Based on 1000 CST data. High, low level, moisture values (depths somewhat uncertain), fairly cold temperatures aloft and frontal system into extreme west and northwest Oklahoma. Weak moisture convergence in END area (primarily speed convergence) with TRW present. Maximum mass convergence is in Kansas along front at present time. Moisture of apparently sufficient depth to suggest TRW and potential for severe activity exists.*

*1100 CST data. Frontal system difficult to locate in Oklahoma but pressure trough and dry air is present. Moisture convergence continues and is increasing in the area of TRW activity in north central Oklahoma but still by way of speed convergence. Pressure trough in west is also an area for possible further development if convergence develops in response to pressure field. Activity should continue and increase in north central Oklahoma in response to increasing heating and outflow boundary generated by the persistent TRW.*

*1200 CST data. Drying and strong moisture gradient exist in southwest Oklahoma but convergence still lacking. Windshift or front has passed HUT and ICT Kansas area possibly indicating windshift extending down into north central Oklahoma further supporting activity there. Band of high and mid-level clouds (which may mark a "subsampling scale" wave with associated PVA and enhanced upward motion) is moving southeast from southwest Kansas and may initiate development in west Oklahoma or strengthen the already very strong activity in north central Oklahoma.*

*1300 CST data. Large pressure falls in southwest Oklahoma continue to make area suspect for future development but convergence has not yet developed significantly. Strong winds in central and west Oklahoma continue to funnel warm very moist unstable air into north central Oklahoma and are moderate at this time.*

*1400 CST data. Increasing convergence both in west and north central Oklahoma. In southwest Oklahoma winds have veered in the dryer air and backed some in more moist air with strong pressure falls continuing. An area of TCU and CB's also is present in the dryer air in west Texas indicating destabilization. Winds have backed at both PNC and END (probably induced by CB's to the southeast) and continued large temperature contrast and strong inflow to area. Continued strong to severe activity in north central Oklahoma.*

*1500 CST data. Basically same as above. Some TCU beginning in southwest Oklahoma. Mid and high cloud band moving southeast toward west and north central Oklahoma. One CB and some TCU developing under east end of cloud band northwest of CB complex in north central Oklahoma. Large pressure falls in southwest Oklahoma gives good possibility for development there. (Weak echo has developed.)*

*1600 CST data. Very strong moisture convergence in north central Oklahoma and large pressure falls at END and PNC. Pressure trough has passed END moving into and further increasing convergence in the north central Oklahoma activity. Mid and high level cloud band now overtaking END, PNC activity with new CB development beneath band. Conditions favorable for increased strength and severity of activity. Strong TRW near CDS area as that activity overtakes dry line.*

*Leslie R. Lemon*

Figure 27. NSSL Operational Nowcast, issued hourly beginning at 1000 CST, on June 13, 1975.

As indicated in the forecast and nowcast, wind and moisture fields were not typical of severe storm days. By 1500 CST an increase in convergence was noticed in hourly data over north-central Oklahoma. The development of the large storms with an immence ice crystal cloud is well documented in the satellite data. The WSR-57 data, both photographic and digital, should be very useful in reconstructing the sequence of development of the Stillwater storm.

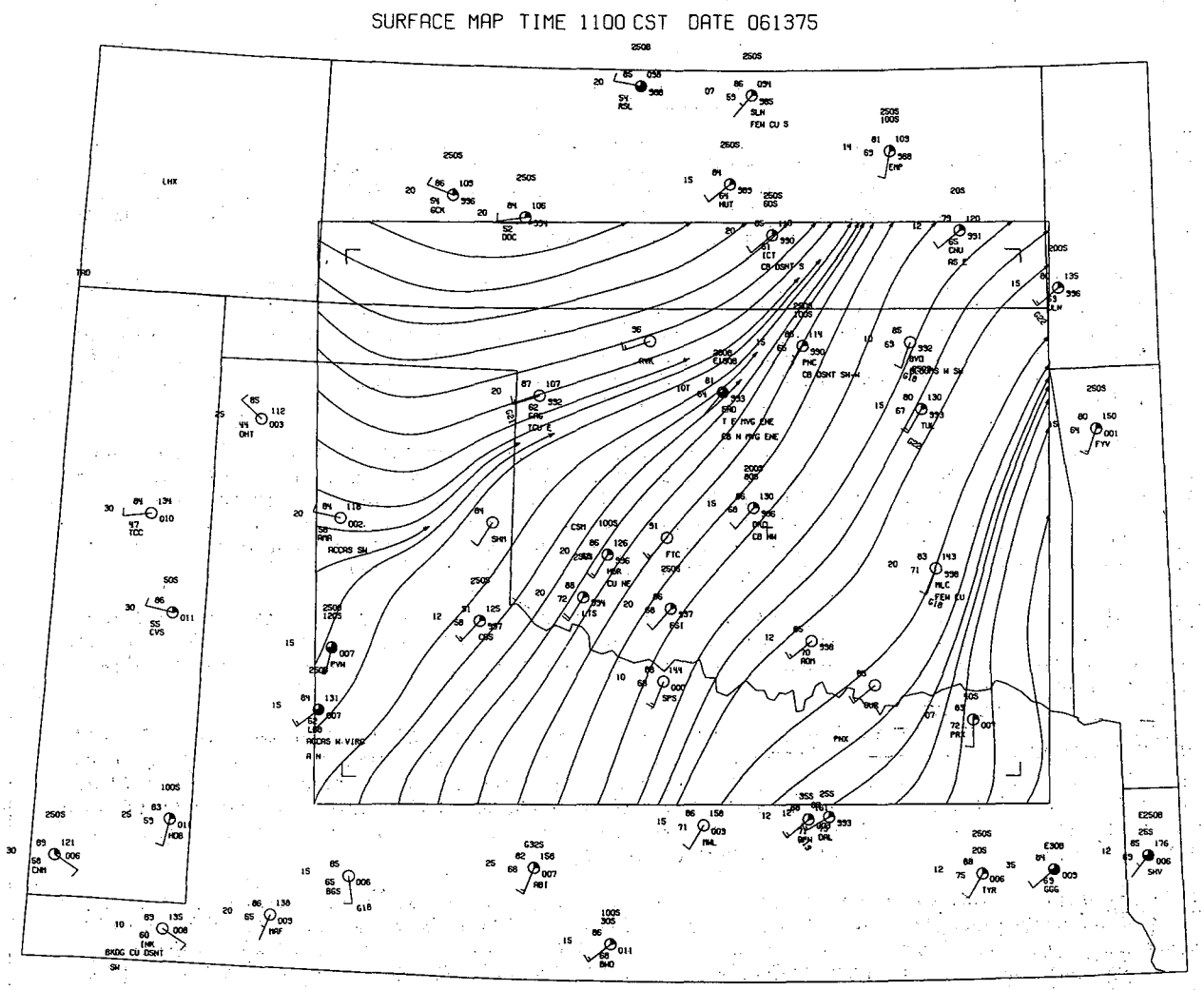
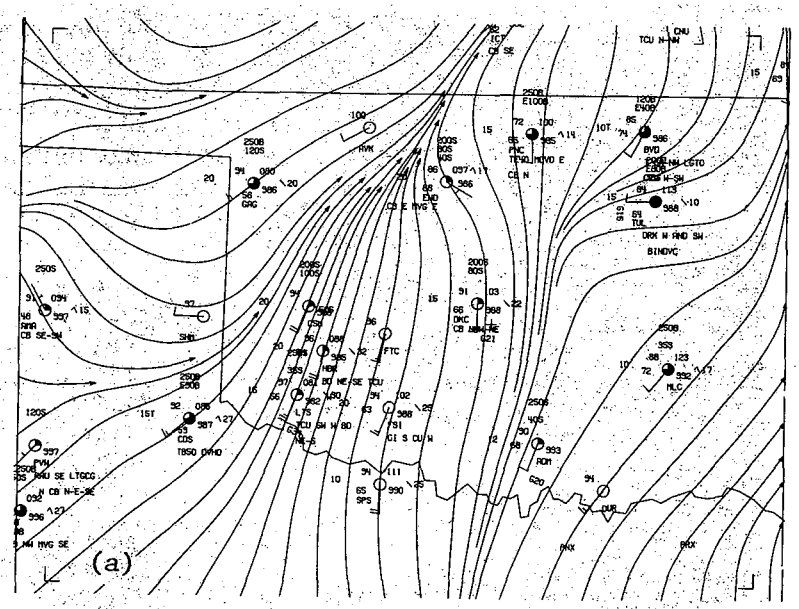
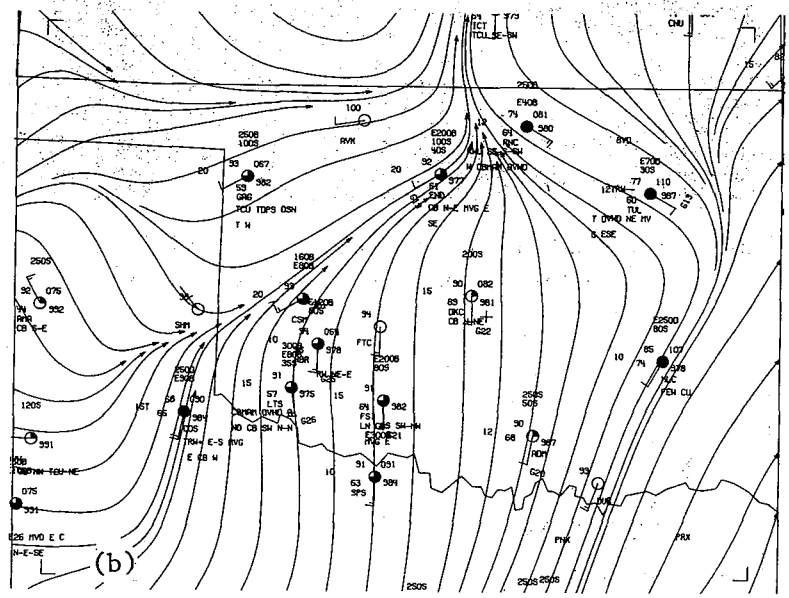
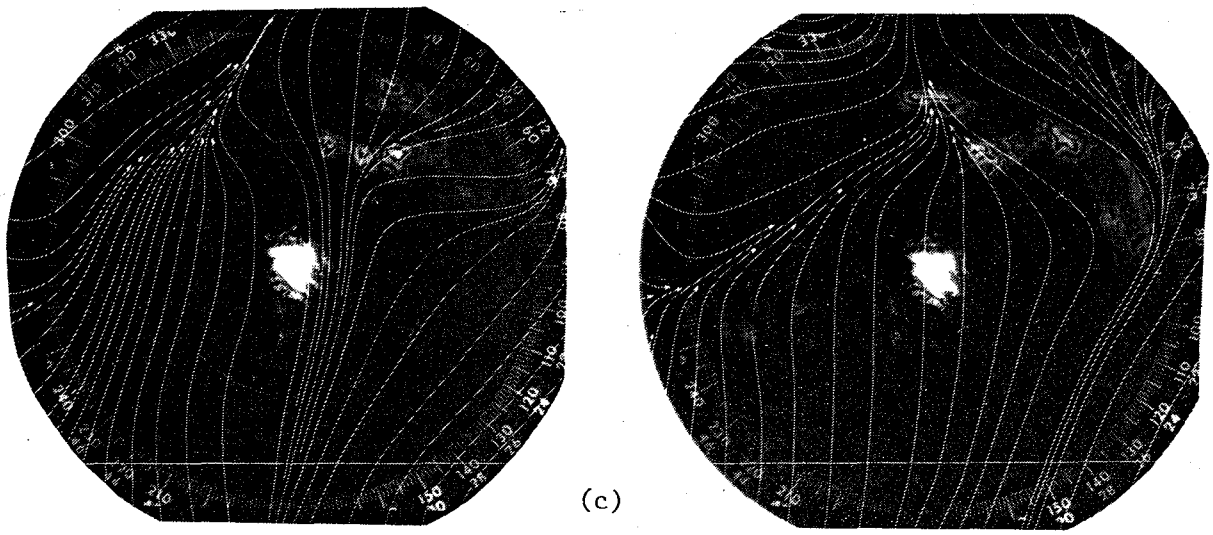



Figure 28. Surface analysis, 1000 CST, June 13, 1975.

Figure 29. Surface flow fields, a) 1500 CST, b) 1700 CST, and c) WSR-57 radar displays showing origin of thunderstorms in zone of convergence over northern Oklahoma.



(c)

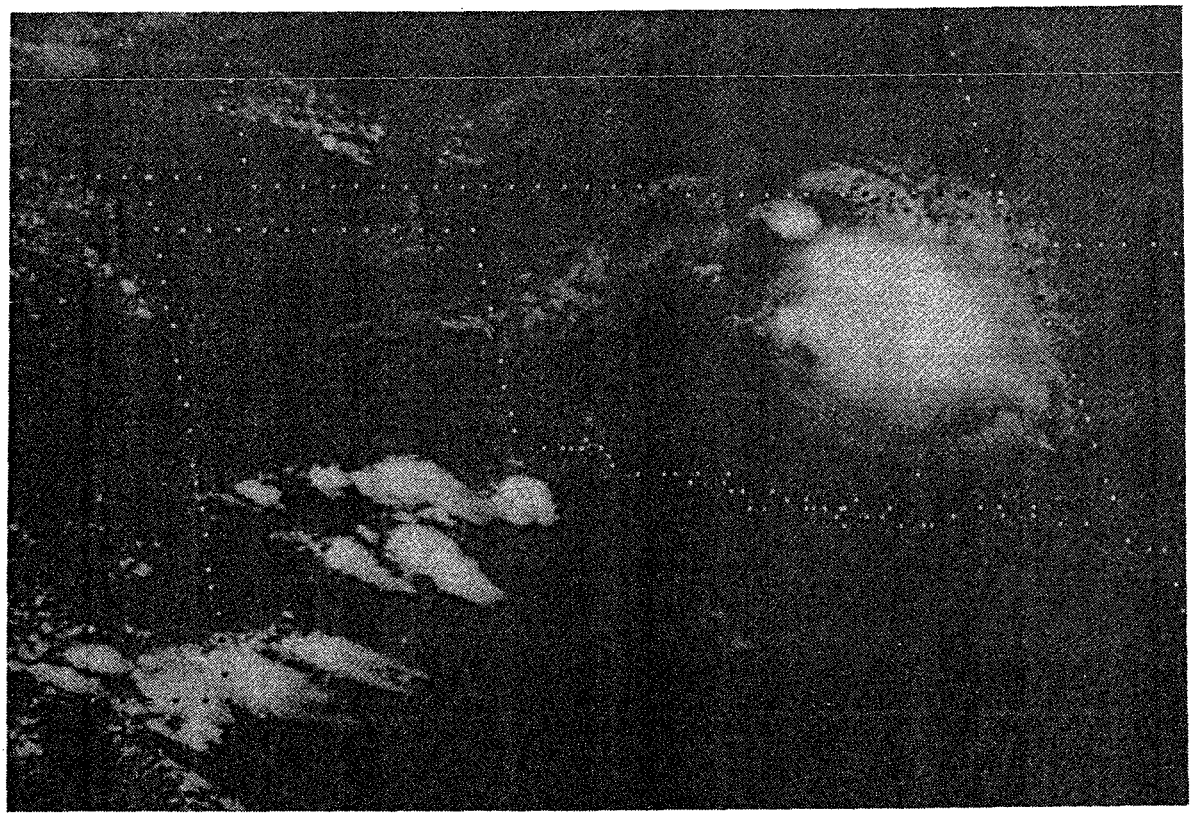


Figure 30. Satellite photograph at 1445 CST, same time as WSR-57 radar profile of precipitation rate, Figure 32.

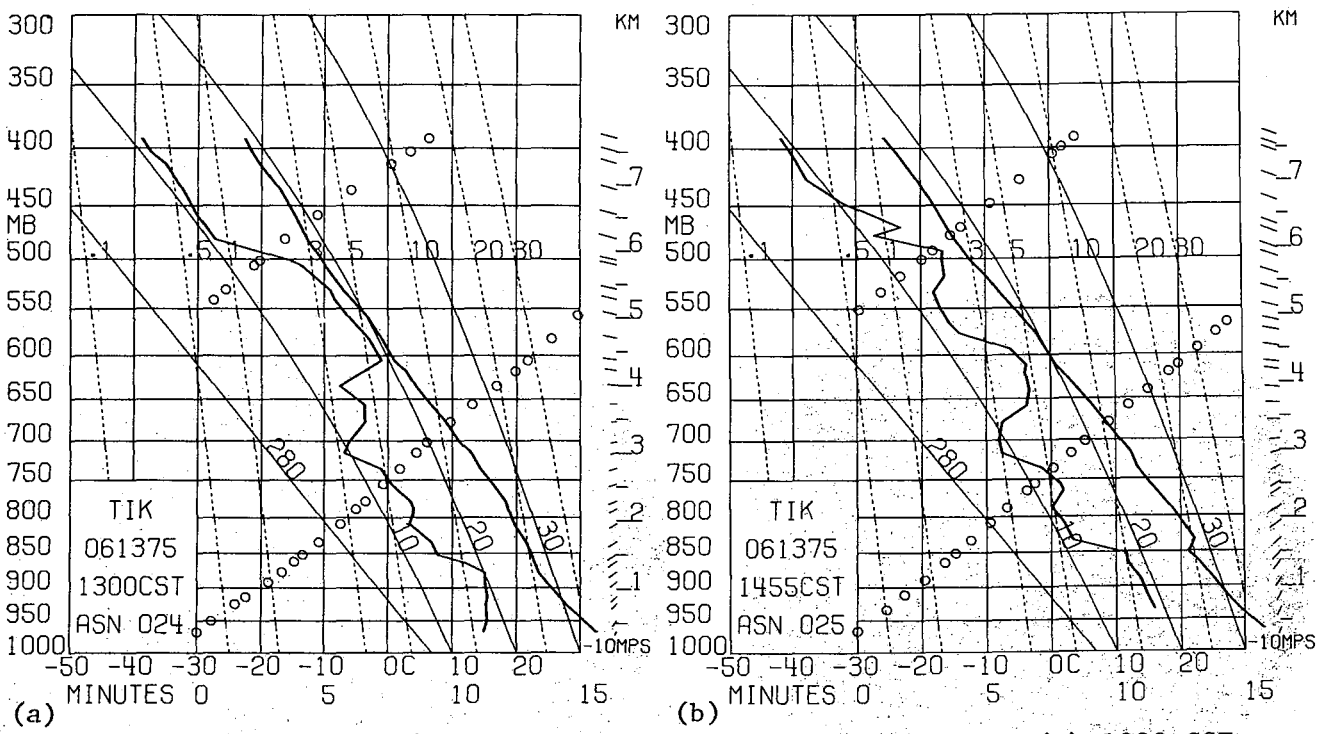



Figure 31. Soundings recorded at Tinker Air Force Base at: (a) 1300 CST, and (b) 1455 CST, 3-4 hours prior to the Stillwater tornado.

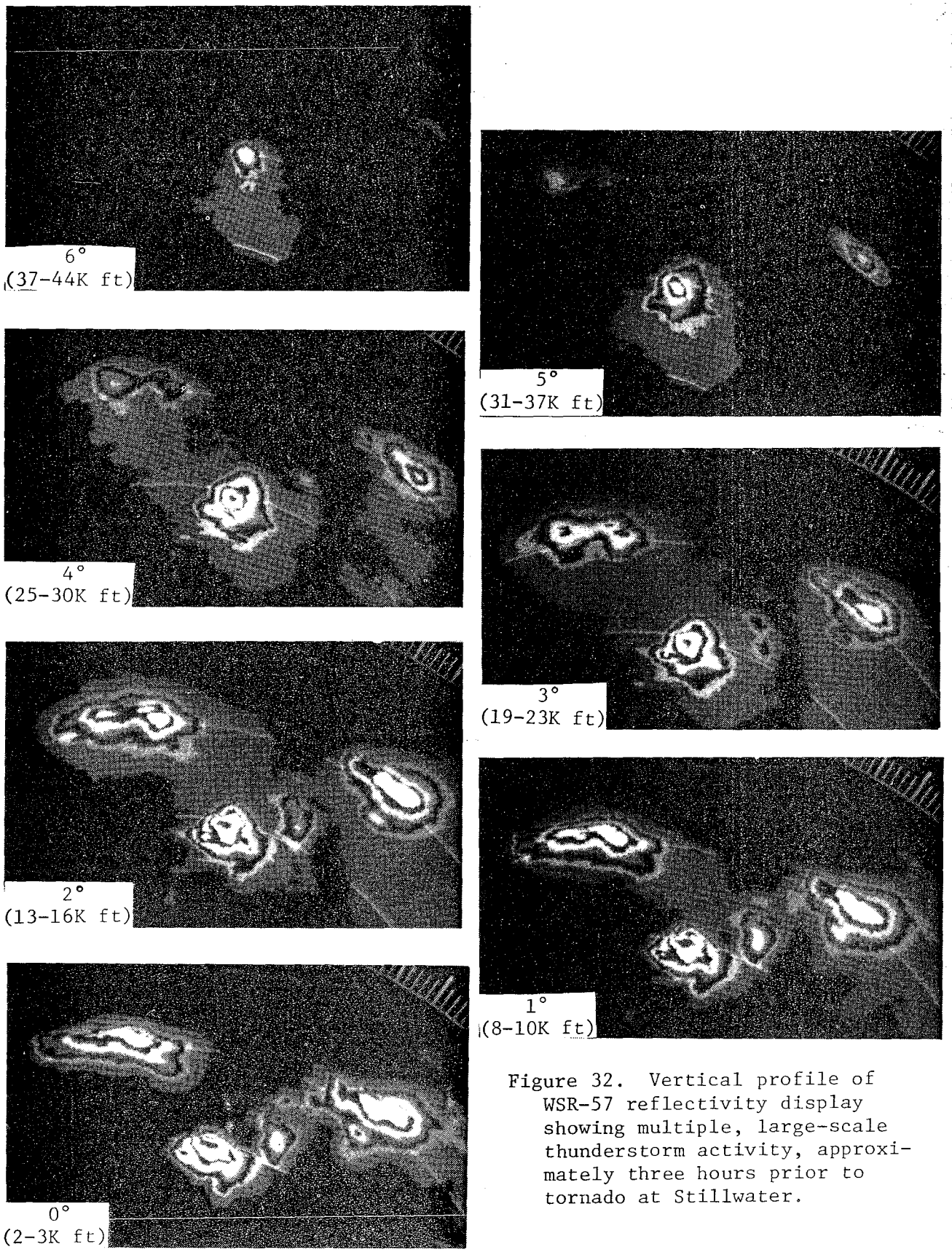



Figure 32. Vertical profile of WSR-57 reflectivity display showing multiple, large-scale thunderstorm activity, approximately three hours prior to tornado at Stillwater.

# STORM DATA SUMMARY
## DATE 061375

| | HOUR 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WSR-57<br>0 DEGREE SECTORS COLLECTED<br>/ = TILTS COLLECTED | | | | | | | | | | | 12 | 12 | 15/ | 16/ | 25/ | 30/ | 16/ | 20/ | 39/ | 38/ | 40/ | 13/ | | |
| DOP NRO<br>MINUTES OF DIGITAL DATA | | | | | | | | | | | | | | | 16 | 10 | | 14 | 24 | 35 | 22 | 15 | | |
| DOP CIM<br>MINUTES OF DIGITAL DATA | | | | | | | | | | | | | | 4 | 18 | 5 | | 5 | 23 | 14 | 10 | 7 | | |
| RAOB<br>RELEASES | | | | | | | | | | | | | | 1 | 1 | | | | | | | | | |
| WKY TOWER<br>OBSERVATIONS PER HOUR | 362 | 360 | 360 | 362 | 363 | 363 | 361 | 213 | 61 | 61 | 11 | | | | 352 | 360 | 361 | 360 | 360 | 316 | 319 | 360 | 362 | 360 |
| MESONET<br>A = ANALOG<br>D = DIGITAL<br>S = TO BE DIGITIZED<br>AD= A AND SOME D | AD | AD | AD | AD | AD | AD | AD | AD | AD | AD | AD | AD | D | D | D | D | D | D | D | D | D | D | D | D |
| AIRCRAFT<br>MINUTES OF DIGITAL DATA NCAR QUEEN AIR | | | | | | | | | | | | | | 56 | 60 | 14 | | 25 | 60 | 60 | 60 | 40 | | |
| AIRCRAFT<br>MINUTES OF DIGITAL DATA AIR FORCE F4C | | | | | | | | | | | | | | | | | | | | | | | | |

Figure 33. Summary of data archived on June 13, 1975.

## SECTION 3

## AUXILIARY INFORMATION

This section contains operating procedures for the rawinsonde program, a list of locations of remote observing facilities, and indices of the data archived.

Figure 34. LuCreta Butcher operates NSSL's Systems Engineering Laboratories 8600. Equipment seen in the background includes an IBM 1401, and a Calmagraphic X-Y reader/plotter system.

**U.S. DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**
ENVIRONMENTAL RESEARCH LABORATORIES

Date : March 21, 1975

To : Rawinsonde Network Personnel

From : Project Coordinator

Subj : NSSL Rawinsonde Operations - 1975

## I. Statement of Objectives

A Rawinsonde Unit from the U.S. Air Force's Sixth Weather Squadron (Mobile) Tinker Air Force Base, Oklahoma, the U.S. Army's Rawinsonde Section at Fort Sill, Oklahoma, and the National Weather Service's Rawinsonde Unit at Oklahoma City, Oklahoma, comprise the network of upper air sites for this spring's thunderstorm observation program during the period 15 April through 15 June. The upper air network is supplemented by an automatic recording surface network, radar observations from NSSL, aircraft operations in and near thunderstorms, an instrumented television tower (WKY-TV) in Oklahoma City, and dual Doppler radars located at Norman and Cimarron Field.

The project meteorologists will use the combined data from all these sources to furnish additional information on the structure and dynamics of severe thunderstorms, and how they interact with their environment. Knowledge gained from these studies will ultimately improve forecasting these destructive storms and related phenomena.

Operationally, the upper air network has these goals:

1. Furnish high quality data in and around thunderstorms
2. Test new operational techniques
3. Furnish support data for aircraft and Doppler radar wind measurement operations and other laboratory special-purpose operations.

The operational specifications described in the following sections are the results of several years operational experience in the field and data reduction experience in the laboratory. The procedures are more unconventional than conventional, but with the purpose of simplifying the task of obtaining scientifically useful data.

II. Network Description

Site specifications are given in Table 1.

III. Daily Routine (7 days per week unless otherwise notified)

A. Period of operation will begin 15 April and end 15 June 1975.

B. Crews should be on site by 1300 CDT unless otherwise notified. When crews are not on site, one member of each crew should be available to receive telephoned instructions, and should know the whereabouts of the other crew members.

C. Perform Daily Check List and other routine maintenance and housekeeping chores.

D. RAOB CONTROL will contact each site by 1330 CDT to obtain station pressure, make time checks, and issue operational instructions. (See Section IX on Communications.)

IV. Soundings (General)

A. Pre-storm and soundings for operational forecasting purposes will be requested at certain times from one or two selected sites. Details on the reduction of these soundings will be passed on at the briefing. Use of a 300 gm balloon normal inflation will be sufficient.

B. Serial soundings using 300 gm balloons, normal inflation 300 m/min will be requested whenever thunderstorms are in or near the network or expected to develop over the network. Release times and heights of soundings will be variable for each station. RAOB CONTROL will determine this during serial sounding operations. Report release time back to RAOB CONTROL as soon as practical.

A WORD OF CAUTION: Don't be too eager! Take time to get preflight calibration checks right. If they are not right, the entire sounding is wasted and cannot be recovered.

V. Data Acquisition

A. Flight preparation and pre-release checks.

1. Balloon inflation

2. GMD

a. If strong winds or heavy precipitation have occurred since the GMD was last checked for orientation and leveling, check again before making release.

b. Keep the electronics of the tracking system in "A-OK" condition. Preventive maintenance should be a matter of daily routine.

3. Control Recorder

   a. Azimuth printer should record 360° when GMD is pointing to true north.

   b. Check condition of printer to insure that verier readings will be legible.

   c. Reset time before each flight.

   d. RESET PRINTING FREQUENCY TO 10 PRINTS PER MINUTE.

   e. Perform other checks in accordance with FMH No. 3 instructions.

4. Baseline check and outside psychrometer check.

   a. A standard baseline check is required according to FMH No. 3 instructions.

   b. Enter baseline values on both the NSSL worksheet and in lines 1 through 4, Blocks 2 and 3 of the RAOB Calibration Form (see instructions in Section VI).

   c. DO NOT CLIP TEST LEADS FROM INSTRUMENT AFTER BASELINE CHECK.

   d. Place instrument outside with the aspirated psychrometer in the instrument shelter provided by NSSL. Moisten the psychrometer wick with distilled water and turn on fan motor. DO NOT ALLOW FAN TO EXHAUST AIR DIRECTLY AT THE RAWINSONDE ELEMENTS.

   e. After one minute, short the reference lead and record a 15-second trace on the TMQ-5.

   f. Immediately after step e, obtain 15-second temperature and humidity traces, and determine the rawinsonde temperature and humidity.

   g. Determine the temperature and humidity from the psychrometer readings. (See Section VIII on psychrometer maintenance.)

   h. If the rawinsonde temperature and humidity differ from the psychrometer values by more than 1°C or 10%, recheck baseline values. If instrument is faulty, reject it and baseline a new instrument. When in doubt, contact RAOB CONTROL for instructions.

   i. Record outside check information in Block 3 of RAOB Calibration Form, and NSSL worksheet (see Section VI).

5. Setting baroswitch

   a. Double check the station barometer reading with the reading from the previous sounding. On a given day, station pressure should not vary more than one to two millibars per hour, unless a vigorous thunderstorm is overhead or a strong cold front has passed.

b. Be especially careful in determining the initial contact setting of the baroswitch. The accuracy of entire sounding depends upon this setting. However, should a discrepancy occur between set contact versus release contact, record the error according to instructions in Section VI, and do not apply the correction when evaluating the TMQ-5 record. The NSSL computer will do this for you.

c. DO NOT ADJUST YOUR BAROMETER UNLESS REQUESTED BY RAOB CONTROL. Your barometer was calibrated at NSSL prior to operations. NSSL will perform a daily computer check of station pressure across the network, and will notify you if your barometer needs further adjustment.

6. TMQ-5 pre-flight preparation

a. Wind stop watch before each sounding.

b. Keep chart drive setting at 1 INCH PER MINUTE.

c. Check ink supply daily.

d. Tension on pen should be set to eliminate overshoot or excessive drag.

e. Check zero ordinate trace for accuracy.

f. Perform other pre-flight checks according to FMH No. 3, EXCEPT it is not necessary to perform sensitivity check prior to each baseline if such a check has already been accomplished as part of the Daily Check List procedures.

g. IMPORTANT: Activate chart drive motor at least one minute before release.

h. The TMQ-5 should be calibrated with a signal generator once every two weeks in accordance with normal procedures.

B. Surface Observation at Release

1. Enter on the NSSL WORKSHEET the surface observation.

2. Estimate surface wind direction and speed and record in meters per second and nearest 10°. (Laboratory personnel will later enter the wind from the recording surface station at your site, but in case that equipment fails, we need your estimate also.)

3. Use the NSSL aspirated psychrometer to determine temperature and relative humidity.

4. Convert psychrometer temperature and humidity to ordinate values, and use these values as the surface recorder record evaluations.

C. In-Flight Check Procedures

1. GMD

   a. Man the GMD on release. It is imperative to get the GMD on target as soon as possible.

   b. The man on the GMD is responsibile for determining the azimuth to the release point on each release. The man releasing the instrument is responsible for pacing of the distance from the release point to the GMD on each release. Record these data as in c and d below.

   c. Enter release azimuth to nearest 10° on the Winds Coding Form-1 in Block 2 at time 00.0.

   d. Enter distance to release point in meters on the RAOB Calibration Form, Line 5, Block 2.

2. Control Recorder

   a. After 2 minutes of flight, switch print frequency to 2 per minute.

   b. Monitor paper feed for legible angle prints.

   c. Monitor signal strength and azimuth-elevation indicators to detect tendency for GMD to hunt or respond erratically. Correct erratic tracking tendencies as soon as feasible

   d. Note on the winds tape the time periods during which the GMD was tracking erratically or hunting.

   e. Operate reference time print switch in AUTOMATIC mode.

3. TMQ-5 Recorder Record

   a. Activate the stop watch coincident with switching the TMQ-5 from S.C. This should be done at the exact moment of instrument release.

   b. Adjust low references regularly and enter on the TMQ-5 record the corrections applied.

   c. Except for attention to reference signals and the general quality of the trace, the recorder chart should require little monitoring during the flight. The operator should closely monitor the control recorder rather than try to evaluate levels on the recorder chart during the flight.

   d. At termination, stop the stop watch at the same time the TMQ-5 is returned to S.C.

      IMPORTANT: Allow recorder to run at least one contact past the required height before turning switch to S.C.

## VI. Procedures for Data Reduction

### A. Recorder Record

1. FMH No. 3 rules are to be followed in picking levels for evaluation EXCEPT SUCCESSIVE LEVELS MAY NOT BE SEPARATED BY MORE THAN 25 MB (exactly 25 mb is allowable) OR BY TWO CONTACTS IN LOW LEVELS.

2. Enter on each significant level the elapsed time since release as discussed in item 4 below, and level number at left side of record starting with level 1 at surface.

3. If changes in temperature and humidity trends allow, it will be more accurate to place levels at the top of the temperature traces (whole contacts). However, do not violate FMH No. 3 rules arbitrarily for this convenience.

4. Determine elapsed time since release using the ruler provided by NSSL. Read times to the nearest 0.01 minute. Begin each measurement from the time when the S.C. signal ended at release (not the time of first trace recording), or from a line drawn across the record at each 6 minutes (the length of the ruler). Be careful to draw levels perpendicular to the ordinate lines.

5. Entries on recorder record at surface level.

   a. Contact value at release.

   b. Ordinate value corresponding to surface temperature from psychrometer reading at release.

   c. Ordinate value corresponding to surface relative humidity from psychrometer reading at release.

   d. Level number 1.

6. VERIFY ALL EVALUATIONS

### B. Entries on RAOB CALIBRATION FORM

Note: Lines are labeled at left side of form. Blocks are labeled at bottom of form. Numbers inside the heavy lines are instructions to computer operator and may be ignored.

| LINE | BLOCK NUMBER | SPECIFICATION |
|---|---|---|
| 1 | 1 | Station identification letters (see Table 1). |
| 2 | | Latitude nearest hundredth degree (see Table 1). |
| 3 | | Longitude nearest hundredth degree (see Table 1). |
| 4 | | Height of barometer in meters. |
| 5 | | Height of GMD antenna in meters. |
| 6 | | Month, day, year (CST). |
| 7 | | Release time nearest minute CST. |
| 8 | | Surface wind direction nearest 10° |
| 9 | | Surface wind speed meters per second (knots x 1.94) |
| 10 | | Radiosonde serial number, last five digits only. |
| 11 | | Ascension number. |
| 12 | | No entries. |
| 1 | 2 | Baseline temperature to nearest 0.1°C. |
| 2 | | Baseline temperature ordinate value to nearest tenth. |
| 3 | | 50.0 is constant. |
| 4 | | Relative humidity ordinate value at 50% relative humidity and +40° after setting humidity evaluator on baseline information. |
| 5 | | Distance from release point to GMD in meters. |
| 6 | | Surface temperature at release to nearest 0.1°C from psychrometer reading. |
| 7 | | 1 is constant. |
| 8 | | Elapsed time of sounding to nearest hundredth minute from ruler measurement of recorder record. Also enter on recorder record, measurement is from S.C. to S.C. |

| | | |
|---|---|---|
| 9 | | Elapsed time of sounding to nearest hundredth minute from stop watch. (See conversion Table 2.) Also enter on Recorder Record, measurement is from S.C. to S.C. |
| 10 | | Correction ± to be applied to commutator bar setting. (Same as line 3, block 4). |
| 11 | | Surface pressure at release* to nearest tenth millibar. |
| 1 | 3 | Baseline temperature ordinate. |
| 2 | | Baseline temperature. |
| 3 | | Baseline humidity ordinate. |
| 4 | | Baseline humidity. |
| 5 | | Outside check temperature ordinate. |
| 6 | | Outside check temperature from Recorder Record. |
| 7 | | Outside check temperature from psychrometer. |
| 8 | | Outside check humidity ordinate. |
| 9 | | Outside check humidity from Recorder Record. |
| 10 | | Outside check humidity from psychrometer. |
| 11 | | Pressure to nearest millibar at beginning of missing data layer. |
| 12 | | Pressure to nearest millibar at end of missing data layer. |
| 13-14 | | Beginning and ending of additional missing data layer. |
| 15 | | If precipitation was occurring at release time at station, enter 1; otherwise enter 0. |
| 16 | | If unusual sustained ascent rate occurred during sounding such as that due to updraft, icing, etc., enter 5; otherwise enter 0. |

* Ordinarily, when pressure reading used for commutator bar setting has been made within 5 minutes of release, that pressure may be used as surface pressure. However, if more than 5 minutes has elapsed, or if a wind shift or temperature drop occurs between setting commutator and release, take another pressure, temperature and humidity reading immediately after release to use as surface values.

| | | |
|---|---|---|
| 1 | 4 | Contact setting value (if greater than 10 shift decimal one place to the right). |
| 2 | | Contact value at release (if greater than 10 shift decimal one place to the right). |
| 3 | | Correction ± to be applied to commutator bar setting (if no correction enter 00.0). |
| 4 | | Radiosonde serial number (last 5 only). |
| 5 | | The top of the first contact after release (example commutator bar came in at 8.2 contacts enter 9). |

D. Entries on WINDS CODING FORM-1

| LINE | BLOCK | TIME | SPECIFICATIONS |
|---|---|---|---|
| 1 | 1 | 00.0 | Elevation angle at release (always 00.00). |
| | 2 | | Azimuth angle to balloon at release. |
| | 3 | 00.1 | Elevation angle. |
| | 4 | | Azimuth angle. |
| | 5 | 00.2 | Elevation angle. |
| | 6 | | Azimuth angle. |
| | 7 | 00.3 | Elevation angle. |
| | 8 | | Azimuth angle. |
| 2-25 | 1-8 | 00.4-41.5 | Elevation azimuth angles entered in the same manner as on Line 1. |

NOTE:
1. All angles should be read to hundredths of a degree.
2. Time increment changes at 2.0 minutes.
3. Angle data must be filled in to complete the line on which termination time falls.
4. For runs exceeding 41.5 minutes, finish entries on Winds Coding For
5. Fill out heading on form.

E. Entries on NSSL Worksheet

Heading

1. Enter station identifier letters.

2. Release data and time (CST).

3. Ascension number.

4. Radiosonde serial number (last 5 only).

Baseline Check Data

1. Make baseline check in accordance with NSSL S.O.P. Chapter V, 4a through 4e.

2. Enter all information in spaces provided.

Outside Check

1. Make in accordance with NSSL S.O.P. Chapter V, 6b, 1 through 4.

2. Enter information in spaces provided.

OTE: FURNISH ALL INFORMATION IN EACH SECTION!

F. Entries on CONTACT SETTING Form

1. Ascension number (numbered sequentially from beginning of season).

2. Surface pressure to the nearest tenth of a mb.

3. Whole Contact Value below setting.

4. Pressure at contact below setting.

5. Pressure at contact above setting.

6. Detent Click Value.

7. Radiosonde serial number (last 5 only).

Note: The above information to be called in to RAOB CONTROL. RAOB CONTRAL will call back the following information.

1. Commutator bar setting, Contact Value to the nearest tenth of a contact.

2. Number of clicks up from lower contact.

Note: Each crew will be furnished a working copy of the contact setting form in acetate and the information may be erased after it is transferred to the NSSL worksheet and RAOB calibration form.

## VII. Procedures for Forwarding Original Records and Forms

A. Envelope Supply:

1. Thirty large, franked, U.S. Government mailing envelopes, return-addressed to NSSL.

2. Forty serially-numbered smaller envelopes for packaging the recorder record, control recorder tape, pressure calibration strip, and coding forms for each run individually.

B. Any run resulting in at least one minute of information will be assigned an ascension number.

C. Some Precautions:

1. Be sure the sounding information is placed in the envelope numbered for that ascension. (A few unnumbered envelopes are included in case a numbered envelope is lost.)

2. Take care not to mix records from one sounding with those from another.

D. The small envelopes should be identified by the following:

1. Station identification letters

2. Date and time of release (CST)

3. Ascension number

E. After the day's soundings have been evaluated and VERIFIED, place the unsealed envelopes in a large envelope, seal, and mail to NSSL at the earliest convenience.

VIII. Maintenance of NSSL Psychrometer

A. The aspirated psychrometer furnished by NSSL should remain a reliable instrument with nominal care. You have been supplied with the most essential items necessary to maintain an accurate instrument. If you exhaust your supplies, notify RAOB CONTROL.

1. Supplies:

a. Six 1.5v batteries (Size D).

b. One quart bottle of distilled water.

c. One small applicator bottle.

d. Wicking and string.

2. Maintenance:

a. Change wicking at least ONCE every WEEK, more often if dusty conditions prevail.

b. Change batteries every THREE weeks to insure an adequate ventilation rate.

B. DO NOT RUN THE PSYCHROMETER MOTOR CONTINUOUSLY FOR PERIOD LONGER THAN 5 MINUTES. Your batteries will maintain power much longer if this suggestion is followed.

IX. Communications

A. NSSL will serve as RAOB CONTROL. The base station call sign is KKE 793, only RAOB CONTROL CAN OPEN THE NETWORK. Telephone: 1-329-0388.

B. All stations are required to have access to commercial telephone at the rawinsonde site and at the personnel billet. When calling NSSL by telephone, CALL COLLECT if long distance.

C. Radio Communications

1. The FM transceivers which NSSL assigns to each site form a dual-channel line-of-sight communications system linking the sites to RAOB CONTROL and in certain instances to each other. RAOB CONTROL will use this means to issue general operational advisories and directives, and individual instructions to

each site. The sites may also use this means to initiate communications with RAOB CONTROL or with adjacent sites. However, you should keep in mind that you are not likely to receive all sites on your set, so take care not to interrupt communications which NSSL is having with another site. Please use discretion in the amount and type of messages transmitted by radio.

2. Except during actual transmission, these radios are to be kept in a ready-to-receive status while the site is manned.

3. NSSL's transceiver is mounted near the top of the WKY-TV tower in Oklahoma City (about 1000 ft above terrain level). These transceivers transmit on a frequency of 173.10 mHz and receive on 163.275 through the NSSL transceiver.

4. In the event of radio malfunction or other transmission difficulties, the telephone link with NSSL is to be used.

5. Transmissions on either the radio or telephone links are restricted to messages pertinent to project operations.

TABLE 1. 1975 Rawinsonde Site Specifications

| Station Number | Location | Code Letters | Latitude | Longitude | Elevation Field/ Barometer | Assigned Frequency |
|---|---|---|---|---|---|---|
| 1 | TAFB | TIK | 35.41 | 97.40 | 1270 ft/387M | 1685 |
| 2 | Fort Sill | FSI | 34.66 | 98.41 | 1180 ft/362M | 1680 |
| 3 | Oklahoma City | OKC | 35.40 | 97.60 | 1286 ft/392M | 1680 |

TABLE II

CONVERSION TABLE SECONDS TO HUNDREDTHS

| Seconds | | Hundredths | Seconds | | Hundredths | Seconds | | Hundredths |
|---|---|---|---|---|---|---|---|---|
| 01 | = | .02 | 21 | = | .35 | 41 | = | .69 |
| 02 | = | .03 | 22 | = | .36 | 42 | = | .70 |
| 03 | = | .05 | 23 | = | .38 | 43 | = | .72 |
| 04 | = | .07 | 24 | = | .40 | 44 | = | .74 |
| 05 | = | .08 | 25 | = | .41 | 45 | = | .75 |
| 06 | = | .10 | 26 | = | .43 | 46 | = | .77 |
| 07 | = | .12 | 27 | = | .45 | 47 | = | .79 |
| 08 | = | .13 | 28 | = | .47 | 48 | = | .80 |
| 09 | = | .15 | 29 | = | .48 | 49 | = | .82 |
| 10 | = | .16 | 30 | = | .50 | 50 | = | .83 |
| 11 | = | .18 | 31 | = | .52 | 51 | = | .84 |
| 12 | = | .20 | 32 | = | .53 | 52 | = | .86 |
| 13 | = | .21 | 33 | = | .55 | 53 | = | .88 |
| 14 | = | .23 | 34 | = | .57 | 54 | = | .80 |
| 15 | = | .25 | 35 | = | .58 | 55 | = | .91 |
| 16 | = | .26 | 36 | = | .60 | 56 | = | .93 |
| 17 | = | .28 | 37 | = | .61 | 57 | = | .95 |
| 18 | = | .29 | 38 | = | .63 | 58 | = | .96 |
| 19 | = | .31 | 39 | = | .65 | 59 | = | .98 |
| 20 | = | .33 | 40 | = | .67 | 60 | = | 1.00 |

ENTRIES ON RAOB CALIBRATION FORM

| Block | Line | |
|---|---|---|
| One | One | The station identifier OUN is Norman. |
| | Two | The latitude is 35.24 to the nearest hundredth. |
| | Three | The longitude is 97.47 to the nearest hundredth. |
| | Four | The height of the barometer is 362 meters. |
| | Five | The height of the antenna is 363 meters. |
| | Six | The date is May 20, 1974. |
| | Seven | The time of release is 1900 CST. |
| | Eight | The surface wind direction is 20 degrees. |
| | Nine | The surface wind speed is 2 meters per second. |
| | Ten | Radiosonde serial number 02643 (last 5 No. only). |
| | Eleven | Ascension number is 49. |
| | Twelve | Leave as is, no entries. |
| Two | One | Enter baseline temperature, 23.8 degrees C. |
| | Two | Enter baseline temperature ordinate from recorder record, 70.9 ordinates. |
| | Three | 50.0, is constant. |
| | Four | After setting humidity evaluator on baseline information, enter ordinate value at 50% relative humidity and +40 degrees C. to the nearest tenth of an ordinate, 75.1 ordinates. |
| | Five | Distance from release point to GMD to the nearest meter, 55 meters. |
| | Six | Surface temperature at release to the nearest 0.1 degree C. from psychrometer reading, 24.8 degrees C. |
| | Seven | 1 is constant. |
| | Eight | Elapsed time of sounding at termination as taken from recorder record to nearest hundredth minute, 19.62 minutes. |

| Block | Line | |
|---|---|---|
| | Nine | Elapsed time of sounding at termination to nearest hundredth minute (see conversion table) as taken from stop watch 20.12 minutes. |
| | Ten | Commutator bar correction, to the nearest tenth of a contact is 0.1. |
| | Eleven | Surface pressure, from barometer to nearest tenth of a millibar, at release, 971.4 mb. |
| Three | One | Baseline temperature ordinate is 70.9. |
| | Two | Baseline temperature was 23.8 degrees C. |
| | Three | Baseline relative humidity ordinate is 80.8. |
| | Four | Baseline relative humidity is 31%. |
| | Five | Outside check temperature ordinate is 71.4. |
| | Six | Outside check temperature converted from ordinate value is 24.8 degrees C. |
| | Seven | Outside temperature from psychrometer at time of check is 24.8 degrees C. |
| | Eight | Outside check relative humidity ordinate is 63.0. |
| | Nine | Outside check relative humidity converted from ordinate value is 63%. |
| | Ten | Outside relative humidity determined from psychrometer reading is 67%. |
| | Eleven | Missing data beginning at 841 millibars. |
| | Twelve | Missing data ending at 805 millibars. |
| | Thirteen<br>Fourteen | Blocks 13 and 14 are used for beginning and ending of additional missing data if encountered. |
| | Fifteen | Precipitation is occurring at station at time of release (if no precipitation enter 0). |
| | Sixteen | Unusual ascent rate occurred at some point during sounding (if no unusual ascent rate occurred enter 0). |

| Block | Line | |
|---|---|---|
| Four | One | Contact setting was 7.4. |
| | Two | Commutator bar came in on 7.5 contacts. |
| | Three | Commutator bar correction is -0.1. |
| | Four | Radiosonde Serial Number is 02643 (last five only). |
| | Five | The top of the first contact after release is 8.0. |

INDEX 1975 RAWINSONDE DATA

| DATE | TIK | FSI |
|---|---|---|
| 050275 | 1305 | |
| 051375 | 1257 | |
| | 1458 | |
| 051975 | 1400 | |
| | 1600 | |
| | 1832 | |
| 052075 | 1402 | |
| 52075 | 1402 | |
| 052275 | 1329 | |
| | 1534 | |
| | 1630 | |
| 052375 | 1357 | |
| 052475 | 1128 | 1219 |
| | 1329 | |
| 052675 | | 1240 |
| 052875 | 1358 | |
| 052975 | 1328 | |
| 060275 | 1545 | |
| 060575 | 1426 | |
| 060675 | 1300 | |
| | 1455 | |
| 060975 | 1359 | |
| 061375 | 1300 | |
| | 1455 | |

INDEX OF ALL RAWINSONDE STATIONS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANA | ANADARKO | | | 1968 | | | | | | | | |
| APA | APACHE | | | 1968 | | | | | | | | |
| BLA | BLANCHARD | | | | 1969 | 1970 | | | | | | |
| CDS | CHILDRESS | 1966 | | | | | | | | | | |
| CHK | CHICKASHA | 1966 | 1967 | 1968 | 1969 | 1970 | | | | | 1974 | |
| CDR | CORDELL | 1966 | 1967 | | | | | | | | | |
| DIB | DIBBLE | | | 1968 | | | | | | | | |
| EDM | EDMOND | | | | | 1970 | 1971 | | | | | |
| ELR | EL RENO | | | | 1969 | 1970 | | | | | 1974 | |
| EXP | EXPRESSWAY | | | | 1969 | | | | | | | |
| FSI | FORT SILL (1) | 1966 | 1967 | 1968 | | | | 1972 | 1973 | 1974 | | |
| FTC | FORT COBB | | | | | | | | | 1974 | | |
| HIN | HINTON | | | 1968 | | | | | | | | |
| LNS | LINDSAY | | | | | | | | | 1974 | | |
| LTS | ALTUS | 1966 | 1967 | | | | | | | | | |
| MAP | MUSTANG AIRPORT | | | | | | 1971 | | | | | |
| MIN | MINCO | | | 1968 | 1969 | 1970 | | | | | | |
| MUS | MUSTANG | | | | 1969 | | | | | | | |
| NEW | NEWCASTLE | | | 1968 | | | | | | | | |
| NOB | NOBLE | | | | | 1970 | | | | | | |
| NRO | NORMAN | | | | 1969 | | 1971 | 1972 | 1973 | | | |
| OKC | OKLAHOMA CITY | 1966 | 1967 | | | | | | | | | |
| OUN | NORMAN | | | | | | | | | 1974 | | |
| PMT | PIEDMONT | | | | 1969 | 1970 | | | | | | |
| PVY | PAULS VALLEY | 1966 | 1967 | | | | | | | | | |
| RIN | RINGLING | 1966 | 1967 | | | | | | | | | |
| RSP | RUSH SPRINGS | | | 1968 | | | | | | | | |
| SPS | WICHITA FALLS | 1966 | 1967 | | | | | | | | | |
| SIL | FORT SILL (2) | | | 1968 | | | | | | | | 1975 |
| TAB | TINKER | | | | | 1970 | | | | | | |
| TIK | TINKER | 1966 | 1967 | | | | | 1972 | 1973 | | | 1975 |
| TVT | WKY TOWER (2) | | | 1968 | | | | | | | | |
| WAT | WATONGA | 1966 | 1967 | | | | | | | | | |
| WHT | WHEATLAND | | | | | 1970 | | | | | | |
| WKY | WKY TOWER (1) | | | 1968 | | | | | | 1974 | | |

ORIGIN NRO (WSR/57) LAT 35. 14. 17. LONG 97. 27. 43.

| | LAT | | | LONG | | | R(KM) | AZ TO | AZ FRM |
|---|---|---|---|---|---|---|---|---|---|
| WHF (NRO DOP) | 35. | 14. | 11. | 97. | 27. | 47. | 0.211 | 208.57 | 28.57 |
| CMF (CIM DOP) | 35. | 28. | 31. | 97. | 48. | 47. | 41.349 | 309.74 | 129.54 |
| TWR (WKY TOWER) | 35. | 34. | 6. | 97. | 29. | 20. | 36.808 | 356.20 | 176.19 |
| OUN (NSSL WBRT) | 35. | 14. | 24. | 97. | 27. | 34. | 0.314 | 46.40 | 226.40 |
| KOCO-TV | 35. | 33. | 44. | 97. | 29. | 23. | 36.135 | 356.01 | 176.00 |
| KWTV | 35. | 32. | 58. | 97. | 29. | 50. | 34.773 | 354.73 | 174.71 |
| WKYA | 35. | 33. | 50. | 97. | 30. | 28. | 36.470 | 353.47 | 173.45 |
| WKYB | 35. | 33. | 43. | 97. | 30. | 30. | 36.261 | 353.35 | 173.33 |
| WKYC | 35. | 33. | 41. | 97. | 30. | 25. | 36.185 | 353.54 | 173.51 |
| WKYD | 35. | 33. | 43. | 97. | 30. | 24. | 36.244 | 353.59 | 173.57 |

ORIGIN WHF (NRO DOP) LAT 35. 14. 11. LONG 97. 27. 47.

| | LAT | | | LONG | | | R(KM) | AZ TO | AZ FRM |
|---|---|---|---|---|---|---|---|---|---|
| CMF (CIM DOP) | 35. | 28. | 31. | 97. | 48. | 47. | 41.391 | 310.03 | 129.82 |
| NRO (WSR/57) | 35. | 14. | 17. | 97. | 27. | 43. | 0.211 | 28.57 | 208.57 |
| TWR (WKY TOWER) | 35. | 34. | 6. | 97. | 29. | 20. | 36.986 | 356.38 | 176.36 |
| OUN (NSSL WBRT) | 35. | 14. | 24. | 97. | 27. | 34. | 0.518 | 39.24 | 219.24 |
| KOCO-TV | 35. | 33. | 44. | 97. | 29. | 23. | 36.313 | 356.19 | 176.18 |
| KWTV | 35. | 32. | 58. | 97. | 29. | 50. | 34.949 | 354.93 | 174.91 |
| WKYA | 35. | 33. | 50. | 97. | 30. | 28. | 36.643 | 353.66 | 173.64 |
| WKYB | 35. | 33. | 43. | 97. | 30. | 30. | 36.433 | 353.55 | 173.52 |
| WKYC | 35. | 33. | 41. | 97. | 30. | 25. | 36.358 | 353.73 | 173.71 |
| WKYD | 35. | 33. | 43. | 97. | 30. | 24. | 36.417 | 353.78 | 173.76 |

ORIGIN CMF (CIM DOP) LAT 35. 28. 31. LONG 97. 48. 47.

| | LAT | | | LONG | | | R(KM) | AZ TO | AZ FRM |
|---|---|---|---|---|---|---|---|---|---|
| WHF (NRO DOP) | 35. | 14. | 11. | 97. | 27. | 47. | 41.391 | 129.82 | 310.03 |
| NRO (WSR/57) | 35. | 14. | 17. | 97. | 27. | 43. | 41.349 | 129.54 | 309.74 |
| TWR (WKY TOWER) | 35. | 34. | 6. | 97. | 29. | 20. | 31.118 | 70.48 | 250.67 |
| OUN (NSSL WBRT) | 35. | 14. | 24. | 97. | 27. | 34. | 41.387 | 129.11 | 309.31 |
| KOCO-TV | 35. | 33. | 44. | 97. | 29. | 23. | 30.820 | 71.62 | 251.81 |
| KWTV | 35. | 32. | 58. | 97. | 29. | 50. | 29.753 | 73.82 | 254.00 |
| WKYA | 35. | 33. | 50. | 97. | 30. | 28. | 29.334 | 70.28 | 250.46 |
| WKYB | 35. | 33. | 43. | 97. | 30. | 30. | 29.215 | 70.65 | 250.83 |
| WKYC | 35. | 33. | 41. | 97. | 30. | 25. | 29.314 | 70.85 | 251.02 |
| WKYD | 35. | 33. | 43. | 97. | 30. | 24. | 29.357 | 70.75 | 250.93 |

NSSL Mesonetwork - 1975

| Station | Ident. | County | Latitude | Longitude | Elevation Feet MSL* | Source Map Scale x $10^2$ |
|---|---|---|---|---|---|---|
| Amber | AMB | Grady | 35°09'05"N | 97°52'52"W | 1240 | 1:240 |
| Amber E | AME | Grady | 35°10'24"N | 97°46'21"W | 1359 | 1:240 |
| Dutton Corner | DUT | Caddo | 35°12'18°N | 98°05'41"W | 1225 | 1:240 |
| Minco A | MNA | Grady | 35°15'36"N | 97°59'19"W | 1379 | 1:240 |
| Minco B | MNB | Grady | 35°16'34"N | 97°55'02"W | 1437 | 1:240 |
| Minco C | MNC | Grady | 35°13'05"N | 97°55'13"W | 1200 | 1:240 |
| Minco D | MND | Grady | 35°15'00"N | 97°56'03"W | 1251 | 1:240 |
| Minco E | MNE | Grady | 35°14'33"N | 97°55'04"W | 1242 | 1:240 |
| Minco F | MNF | Grady | 35°14'24"N | 97°57'13"W | 1251 | 1:240 |
| Minco G | MNG | Grady | 35°16'11"N | 97°57'10"W | 1402 | 1:240 |
| Minco NE | ONE | Grady | 35°19'07"N | 97°53'43"W | 1317 | 1:240 |
| Minco SW | MSW | Grady | 35°15'23"N | 98°02'30"W | 1412 | 1:240 |
| Minco W | MNW | Grady | 35°20'02"N | 97°59'47"W | 1402 | 1:240 |
| NSSL CHK | CHK | Grady | 35°06'07"N | 97°57'43"W | 1148 | 1:240 |
| Pocasset SW | PSW | Grady | 35°10'27"N | 98°00'44"W | 1219 | 1:240 |
| Tuttle | TUT | Grady | 35°17'32"N | 97°49'45"W | 1298 | 1:240 |
| Tuttle S | TTS | Grady | 35°13'38"N | 97°51'12"W | 1273 | 1:240 |

*Add four (4) feet to get the elevations of the instrument shelter.

NSSL SUBSYNOPTIC NETWORK - 1975

| Station | Ident. | County | Latitude | Longitude | Elevation Feet MSL* | Source Map Scale x $10^2$ |
|---|---|---|---|---|---|---|
| Ada | ADA | Pontotoc | 34°48'14"N | 96°40'28"W | 1008 | 1:240 |
| Alva | AVK | Woods | 36°46'37"N | 98°40'02"W | 1470 | 1:240 |
| Cheyenne | CHE | Roger Mills | 35°36'33"N | 99°42'01"W | 2035 | 1:625 |
| Choctaw | CHO | Oklahoma | 35°29'54"N | 97°16'04"W | 1160 | 1:240 |
| Clinton Sherman | CSM | Washita | 35°21'23"N | 99°11'53"W | 1919 | 1:625 |
| Durant | DUR | Bryan | 33°56'39"N | 96°23'51"W | 690 | 1:625 |
| Edmond | EDM | Oklahoma | 35°39'16"N | 97°28'38"W | 1200 | 1:240 |
| El Reno | ELR | Canadian | 35°31'09"N | 97°58'27"W | 1392 | 1:240 |
| Ft. Cobb | FTC | Caddo | 35°08'53"N | 98°28'01"W | 1379 | 1:625 |
| Lindsay | LNS | Garvin | 34°47'08"N | 97°36'33"W | 1135 | 1:240 |
| NSSL (50' TWR) | MWF | Cleveland | 35°14'13"N | 97°27'43"W | 1175 | 1:240 |
| Perkins | SWS | Payne | 35°59'57"N | 97°02'39"W | 965 | 1:625 |
| Seiling | SEL | Dewey | 36°06'04"N | 98°55'27"W | 1925 | 1:250 |
| Shamrock | SHM | Wheeler | 35°14'24"N | 100°11'30"W | 2369 | 1:100 |
| Watonga | WAT | Blaine | 35°51'35"N | 98°25'09"W | 1534 | 1:240 |
| NSSL's Radar, Rawinsonde, and Tower Facilities | | | | | | |
| NSSL (Radar) | NRO | Cleveland | 35°14'17"N | 97°27'43"W | 1175 | 1:240 |
| NSSL (Doppler) | WHF | Cleveland | 35°14'11"N | 97°27'47"W | 1172 | 1:240 |
| WKY Tower | TWR | Oklahoma | 35°34'06"N | 97°29'20"W | 1148 | 1:240 |
| Cimarron Field | CMF | Canadian | 35°28'33"N | 97°48'47"W | 1310 | 1:240 |
| NSSL (WBRT) | OUN | Cleveland | 35°14'24"N | 97°27'34"W | 1183 | 1:240 |

*Add four (4) feet to get the elevations of the instrument shelter.

# APRIL 1975 ARCHIVED RADAR

NUMBER OF ZERO DEGREE TILT SECTORS COLLECTED

| DATE \ HOUR | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | 94 | 186 | 169 | 144 | 9 | | | |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | | | 5 | 12 | 25 | 12 | 12 | 1 | |
| 18 | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | 8 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| 23 | 12 | 12 | 12 | 12 | 12 | 12 | | | | | | | | | | 6 | 11 | | 8 | 12 | 12 | 12 | 12 | 12 |
| 24 | 12 | 12 | 12 | 12 | 12 | 12 | 3 | | | | | | | | | | | 19/ | 24/ | 10/ | 12 | 12 | 12 | 12 |
| 25 | 12 | 12 | 12 | 12 | 12 | 8 | | | | | | | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | 5 | 12 | 12 | 28 | 86 | 98 | 71/ | 44 | 12 | 12 | 12 | 12 |
| 28 | 12 | 12 | 12 | 12 | 12 | 12 | 5 | | | | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | | | | | | 143 | 115 | | | | |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | |

/ -TILT DATA COLLECTED

# MAY 1975 ARCHIVED RADAR

NUMBER OF ZERO DEGREE TILT SECTORS COLLECTED

| DATE \ HOUR | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | 49 | 178 | 31 | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | 9 | 12 | 9 | | 11 | 12 | 12 | 12 | 12 | 14/ | 6 | | | |
| 10 | | | | | | | | 11 | 10/ | 8 / | 12 | 12 | 12 | | | | | | 5 | 10 | | | | |
| 11 | | | | | | | | | 0 / | 11/ | 12 | 7 | | | 4 / | 10/ | | | | | | | | |
| 12 | | | | | | 7 | 12 | 14/ | 6 | 9 / | 20/ | 12/ | 1 | | | | | | | | | | | |
| 13 | | | | | | 9 / | 13/ | 48/ | 18/ | 15/ | 6 | | 11/ | 29/ | 17/ | 13/ | 4 / | 8 / | 13/ | 14/ | 10/ | | | |
| 14 | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | 12 | 12 | 14/ | 27/ | 13/ | 53/ | 18/ | 14/ | 15/ | 12/ | 3 | | | |
| 20 | | | | | | 9 | 12 | 3 | | | | | | | | 12 | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | 4 | 12 | 60/ | 3 / | | | | |
| 22 | | | | | | | | | | | 2 | 15/ | 18/ | 17/ | 17/ | 17/ | 48/ | 51/ | 115 | | | | | |
| 23 | | | | | | 7 | 12 | 11 | 12 | 17/ | 11/ | 12 | 10 | 4 | 12 | 12 | | | | | | | | |
| 24 | | | | | | | | 4 | 12 | 12 | 11 | 12/ | 24/ | 12 | 12 | 22/ | 10/ | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | |
| 26 | | | | | | | | 4 | 14/ | 11/ | 14/ | 8 / | 4 / | 0 / | 15/ | 32/ | 28/ | 28/ | 15/ | 12/ | | | | |
| 27 | | | | | | 7 | 11/ | 12 | 12 | 12 | 1 | | | | | | | | | | | | | |
| 28 | | | | | | 1 | 12 | 12 | 73 | 47 | 12 | 12 | 5 | 12 | 12 | 12 | | | | | | | | |
| 29 | | | | | | | 11 | 165 | 180 | 167 | 54 | 12 | 8 | 7 | 19/ | 29/ | 28/ | 12 | 12 | 120 | 152 | 138 | 7 | |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | | | | | | | | | |

/ -TILT DATA COLLECTED

# JUNE 1975 ARCHIVED RADAR

NUMBER OF ZERO DEGREE TILT SECTORS COLLECTED

| DATE \ HOUR | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | 3 | 12 | 12 | 19/ | 27/ | 21/ | | |
| 5 | | | | | | 5 | 12 | 8 | | | | | | 9 / | 14/ | 16/ | 18/ | 18/ | 24/ | 25/ | 3 / | | | |
| 6 | | | | | | | | | | | | | | | 5 | 11 | | | | | 16/ | 20/ | 17/ | 14/ |
| 7 | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | 12/ | 17/ | 12 | 12 | 12 | 23/ | 25/ | 21/ | 24/ | 4 / | | |
| 9 | | | | | | 4 | 9 | 3 | 15/ | 12 | 8 | | | 5 | 29/ | 29/ | 26/ | | | | | | | |
| 10 | | | | | | 10 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 53 | 12 | 12 | 3 | | | | | | | |
| 11 | | | | | | 7 | 12 | 12 | 11 | 12 | 12 | 12 | 11 | | | | | | | 1 | | 0 / | 0 / | |
| 12 | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | 12 | 12 | 15/ | 16/ | 25/ | 30/ | 16/ | 20/ | 39/ | 38/ | 40/ | 13/ | | |
| 14 | | | | | | | | | 71 | 104 | 1 | 12 | 6 | 6 | 6 | 6 | 1 | | 11/ | 5 / | | | | |
| 15 | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | 4 | 12 | 12 | 12 | 12 | 13 | 12 | 6 | | |
| 17 | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | |

/ -TILT DATA COLLECTED

## MAY 1975 DOPPLER ( RAW DATA )

TOTAL MINUTES OF DIGITAL DATA

N-NORMAN C-CIMARRON H-HIGH PRF

| DATE \ HOUR | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | | | | | | | | | | | | | | | |
| 19 | | | | | | 5N<br>7C | 7N<br>2C | 7N<br>5C | | 6N<br>2C | 15N<br>16C | 6N<br>2C | | | |
| 20 | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | |
| 22 | | | | | 1N | 24N<br>6C | 7N<br>6C | 16C | 28NH<br>4C | | | | | | |
| 23 | | 19C | | | | | | | | | | | | | |
| 24 | | | | 3N | | | 15N | 4N | | | | | | | |
| 25 | | | 6C | 5C | | | | | | | | | | | |
| 26 | | | 7N | | 5N | 3N | 16N | 7N | | | | | | | |
| 27 | | 1C | | | 4C | 4C | | | | | | | | | |
| 28 | | | | | | | | | | | | | | | |
| 29 | | | | | | | 17N<br>6C | 3C | | 6NH | 14NH | 32NH | 1N | | |
| 30 | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | |

## JUNE 1975 DOPPLER ( RAW DATA )

TOTAL MINUTES OF DIGITAL DATA

N-NORMAN C-CIMARRON H-HIGH PRF

| DATE \ HOUR | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | | | 6N<br>8C | 15N<br>11C | 12N<br>7C | | | | |
| 6 | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | |
| 8 | | 1N | 23N | 37N | 10NH<br>21C | 16C | | 13N<br>20C | 13N<br>11C | | | |
| 9 | | | | | | | | | | | | |
| 10 | | | | | | | 19C | | | | | |
| 11 | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 13 | | 4C | 16N<br>19C | 10N<br>5C | | 14N<br>5C | 23N<br>23C | 35N<br>14C | 22N<br>12C | 15N<br>7C | | |
| 14 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |

# APRIL 1975 WKY TOWER

NUMBER OF OBSERVATIONS PER HOUR

| DATE \ HOUR | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | 273 | 362 | 360 | 360 | 360 | 360 | 360 | 361 | 361 |
| 8 | 361 | 360 | 361 | 360 | 360 | 361 | 361 | 343 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 362 | 360 | 360 | 360 | 361 | 361 | 363 | 359 | 360 |
| 9 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 328 | 360 | 360 | 360 | 360 | 360 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 360 | 360 | 360 |
| 10 | 359 | 361 | 360 | 361 | 362 | 360 | 360 | 345 | 359 | 361 | 362 | 361 | 360 | 361 | 359 | 361 | 361 | 361 | 361 | 363 | 361 | 361 | 360 | 361 |
| 11 | 360 | 361 | 361 | 359 | 360 | 361 | 361 | 361 | 345 | 360 | 361 | 361 | 359 | 361 | 360 | 360 | 361 | 360 | 360 | 361 | 359 | 360 | 360 | 361 |
| 12 | 359 | 359 | 361 | 360 | 360 | 360 | 360 | 334 | 360 | 362 | 359 | 362 | 360 | 360 | 360 | 361 | 361 | 360 | 360 | 359 | 361 | 361 | 361 | 360 |
| 13 | 360 | 360 | 361 | 361 | 360 | 360 | 361 | 345 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 360 | 361 | 360 | 361 | 361 | 361 | 360 | 360 | 361 |
| 14 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 337 | 361 | 360 | 360 | 360 | 361 | 361 | 360 | 360 | 360 | 361 | 360 | 360 | 360 | 361 | 360 | 360 |
| 15 | 361 | 361 | 360 | 360 | 360 | 359 | 361 | 359 | 345 | 361 | 360 | 361 | 360 | 360 | 360 | 360 | 360 | 361 | 361 | 360 | 360 | 360 | 360 | 360 |
| 16 | 360 | 360 | 360 | 360 | 360 | 361 | 360 | 346 | 361 | 360 | 361 | 360 | 360 | 360 | 361 | 361 | 361 | 361 | 360 | 360 | 360 | 360 | 360 | 361 |
| 17 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 337 | 362 | 360 | 360 | 360 | 361 | 360 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 |
| 18 | 360 | 360 | 360 | 361 | 360 | 361 | 360 | 344 | 360 | 361 | 362 | 361 | 360 | 242 | 124 | 361 | 360 | 363 | 360 | 360 | 360 | 360 | 361 | 360 |
| 19 | 360 | 361 | 361 | 360 | 360 | 360 | 361 | 337 | 360 | 360 | 361 | 360 | 360 | 360 | 360 | 362 | 362 | 360 | 360 | 361 | 360 | 361 | 360 | 360 |
| 20 | 360 | 360 | 360 | 360 | 361 | 360 | 233 | 185 | 360 | 360 | 361 | 360 | 361 | 360 | 360 | 362 | 360 | 360 | 360 | 361 | 360 | 360 | 361 | 361 |
| 21 | 360 | 361 | 360 | 362 | 361 | 360 | 361 | 344 | 360 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 360 | 360 |
| 22 | 361 | 360 | 363 | 360 | 360 | 360 | 183 | 298 | 360 | 360 | 360 | 361 | 360 | 361 | 361 | 360 | 360 | 360 | 360 | 361 | 360 | 360 | 361 | 360 |
| 23 | 360 | 360 | 360 | 360 | 361 | 360 | 360 | 341 | 362 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 359 | 360 | 360 | 360 | 361 | 361 | 360 | 360 |
| 24 | 361 | 360 | 359 | 361 | 360 | 360 | 361 | 342 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 360 | 362 | 360 | 361 | 360 | 360 |
| 25 | 360 | 361 | 360 | 360 | 360 | 361 | 360 | 362 | 343 | 362 | 361 | 360 | 361 | 360 | 360 | 361 | 360 | 361 | 361 | 359 | 359 | 360 | 360 | 360 |
| 26 | 360 | 360 | 360 | 361 | 360 | 360 | 360 | 337 | 360 | 360 | 360 | 360 | 360 | 361 | 359 | 361 | 360 | 360 | 360 | 359 | 360 | 360 | 360 | 360 |
| 27 | 360 | 359 | 361 | 361 | 360 | 361 | 359 | 345 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 359 | 360 | 360 | 360 | 360 | 362 | 360 | 361 | 361 |
| 28 | 361 | 360 | 360 | 360 | 361 | 360 | 360 | 360 | 335 | 360 | 360 | 361 | 360 | 360 | 361 | 359 | 361 | 360 | 360 | 360 | 360 | 360 | 361 | 361 |
| 29 | 360 | 361 | 360 | 360 | 360 | 361 | 361 | 344 | 361 | 360 | 361 | 360 | 360 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 361 |
| 30 | 360 | 360 | 361 | 360 | 360 | 360 | 361 | 361 | 360 | 360 | 343 | 360 | 360 | 361 | 360 | 360 | 360 | 361 | 360 | 360 | 360 | 360 | 360 | 360 |

# MAY 1975 WKY TOWER

NUMBER OF OBSERVATIONS PER HOUR

| DATE \ HOUR | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 360 | 360 | 360 | 360 | 361 | 360 | 360 | 360 | 360 | 349 | 360 | 360 | 360 | 361 | 361 | 360 | 360 | 360 | 236 | 94 | 110 | 79 | 5 | 96 |
| 2 | 188 | 202 | 260 | 78 | | | | 287 | 360 | 259 | 360 | 360 | 110 | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | 186 | 360 | 361 | 361 | 360 | 360 | 361 | 360 | 360 |
| 6 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 334 | 360 | 360 | 361 | 360 | 360 | 361 | 361 | 360 | 360 | 360 | 361 | 360 | 360 | 360 | 361 | 360 |
| 7 | 360 | 360 | 361 | 360 | 359 | 361 | 360 | 340 | 360 | 360 | 361 | 360 | 361 | 360 | 360 | 360 | 360 | 361 | 359 | 360 | 361 | 361 | 359 | 361 |
| 8 | 360 | 360 | 359 | 360 | 361 | 361 | 360 | 342 | 360 | 363 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 362 | 360 | 360 |
| 9 | 361 | 359 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 321 | 294 | 360 | 360 | 360 | 361 | 360 | 359 | 360 | 359 | 361 | 360 |
| 10 | 360 | 360 | 360 | 361 | 360 | 360 | 359 | 343 | 360 | 359 | 360 | 360 | 360 | 361 | 360 | 360 | 361 | 360 | 360 | 360 | 361 | 360 | 360 | 360 |
| 11 | 360 | 360 | 360 | 345 | | | | | | 309 | 359 | 362 | 359 | 361 | 359 | 361 | 360 | 360 | 359 | 360 | 360 | 361 | 360 | 360 |
| 12 | 360 | 360 | 360 | 361 | 360 | 361 | 359 | 359 | 325 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 360 | 359 | 360 | 360 | 360 | 360 | 360 |
| 13 | 359 | 360 | 360 | 358 | 361 | 360 | 360 | 337 | 355 | 360 | 360 | 360 | 271 | 360 | 360 | 331 | 267 | 360 | 360 | 359 | 359 | 361 | 360 | 360 |
| 14 | 359 | 360 | 360 | 361 | 361 | 360 | 360 | 337 | 360 | 108 | | | | | | | | | | | | | | |
| 15 | | | | | | | | 153 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 |
| 16 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 345 | 360 | 359 | 360 | 359 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 |
| 17 | 360 | 360 | 360 | 360 | 360 | 361 | 360 | 342 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 |
| 18 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 360 | 360 | 360 | 340 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 |
| 19 | 360 | 360 | 360 | 360 | 360 | 361 | 360 | 344 | 361 | 360 | 360 | 359 | 358 | 360 | 360 | 360 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 360 |
| 20 | 360 | 360 | 360 | 361 | 360 | 361 | 360 | 338 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 362 | 358 | 361 | 360 | 360 | 360 |
| 21 | 360 | 360 | 360 | 360 | 360 | 359 | 360 | 340 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 360 | 360 | 360 | 360 | 360 | 360 |
| 22 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 336 | 360 | 360 | 359 | 360 | 356 | 360 | 360 | 360 | 360 | 359 | 122 | | | | | |
| 23 | | | | | | | | | | 157 | 359 | 361 | 360 | 360 | 360 | 359 | 359 | 360 | 361 | 359 | 359 | 360 | 360 | 360 |
| 24 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 329 | 360 | 360 | 359 | 359 | 360 | 359 | 359 | 360 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 360 |
| 25 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 344 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 |
| 26 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 339 | 364 | 361 | 361 | 362 | 360 | 363 | 361 | 360 | 360 | 360 | 360 | 361 | 360 | 361 | 360 | 360 |
| 27 | 360 | 360 | 361 | 360 | 360 | 361 | 360 | 361 | 345 | 361 | 360 | 360 | 361 | 361 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 362 | 360 | 360 |
| 28 | 360 | 363 | 360 | 360 | 364 | 360 | 360 | 341 | 1184 | 1121 | 360 | 362 | 360 | 360 | 362 | 360 | 360 | 360 | 361 | 361 | 360 | 360 | 360 | 360 |
| 29 | 360 | 360 | 361 | 360 | 361 | 361 | 361 | 360 | 239 | 360 | 360 | 361 | 360 | 360 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 360 |
| 30 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 341 | 360 | 360 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 363 | 361 | 360 | 360 | 360 | 360 | 360 |
| 31 | 360 | 360 | 360 | 360 | 361 | 360 | 359 | 339 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 |

# JUNE 1975 WKY TOWER

NUMBER OF OBSERVATIONS PER HOUR

| DATE \ HOUR | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 360 | 360 | 360 | 363 | 360 | 363 | 360 | 367 | 361 | 363 | 341 | 362 | 360 | 364 | 362 | 361 | 363 | 360 | 363 | 361 | 365 | 361 | 364 | 365 |
| 2 | 362 | 361 | 362 | 361 | 361 | 361 | 362 | 342 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 363 | 360 |
| 3 | 361 | 361 | 362 | 360 | 361 | 360 | 362 | 344 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 359 |
| 4 | 360 | 359 | 360 | 360 | 345 | 360 | 360 | 341 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 359 | 360 | 360 | 360 | 360 | 360 | 360 | 359 | 359 |
| 5 | 360 | 359 | 360 | 359 | 360 | 360 | 360 | 360 | 345 | 360 | 360 | 360 | 360 | 359 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 |
| 6 | 360 | 360 | 360 | 360 | 359 | 360 | 360 | 360 | 343 | 360 | 360 | 360 | 360 | 359 | 359 | 360 | 360 | 360 | 360 | 359 | 360 | 358 | 88 | |
| 7 | | | | | | | | | 199 | 361 | 360 | 359 | 360 | 359 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 359 | 360 |
| 8 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 359 | 359 | 360 | 359 | 360 | 359 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 360 | 360 |
| 9 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 332 | 360 | 360 | 359 | 360 | 360 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 |
| 10 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 342 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 361 | 360 | 360 | 360 | 360 | 360 | 360 |
| 11 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 335 | 359 | 361 | 368 | 364 | 367 | 360 | 362 | 363 | 361 | 363 | 362 | 361 | 362 |
| 12 | 361 | 365 | 361 | 361 | 361 | 360 | 360 | 361 | 362 | 360 | 361 | 362 | 361 | 361 | 361 | 361 | 361 | 363 | 360 | 360 | 364 | 361 | 361 | 360 |
| 13 | 362 | 360 | 360 | 362 | 363 | 353 | 361 | 213 | 61 | 61 | 11 | | | | 352 | 360 | 361 | 360 | 360 | 316 | 319 | 360 | 362 | 360 |
| 14 | 364 | 361 | 363 | 361 | 360 | 361 | 360 | 331 | 360 | 361 | 363 | 361 | 360 | 361 | 361 | 361 | 360 | 360 | 360 | 360 | 360 | 360 | 363 | 360 |
| 15 | 360 | 362 | 361 | 360 | 360 | 360 | 360 | 363 | 361 | 361 | 360 | 361 | 360 | 362 | 360 | 360 | 360 | 360 | 361 | 162 | | | | |
| 16 | | | | | | | | 47 | 63 | 64 | 61 | 63 | 62 | 65 | 61 | 61 | 61 | 65 | 62 | 61 | 62 | 45 | | |
| 17 | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | | 54 | 61 | 60 | 60 | 62 | 62 | 60 | 60 | 60 | 61 |
| 28 | 60 | 62 | 63 | 61 | 61 | 61 | 62 | 62 | 64 | 62 | 62 | 60 | 60 | 60 | 61 | 60 | 61 | 61 | 62 | 61 | 61 | 61 | 62 | 61 |
| 29 | 61 | 63 | 65 | 61 | 61 | 61 | 64 | 61 | 62 | 64 | 62 | 62 | 61 | 62 | 61 | 62 | 63 | 62 | 60 | 61 | 63 | 62 | 64 | 61 |
| 30 | 64 | 61 | 62 | 61 | 62 | 61 | 62 | 38 | | | | | | | | 40 | 62 | 65 | 63 | 61 | 62 | 66 | 61 | 61 |

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# OBJECTIVES AND ACCOMPLISHMENTS OF THE NSSL 1975 SPRING PROGRAM

## PART II

## RADAR QUALITY CONTROL PROGRAM

D. Sirmans, J. Dooley, J. Carter, and W. Bumgarner

National Severe Storms Laboratory
Norman, Oklahoma
July 1976

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# INTRODUCTION

The accuracy of NSSL's weather radar data can be estimated generally by comparison with raingages (Wilson, 1970; Brandes, 1974), or by comparison among radars. However, it is obviously important to routinely examine the various receiver and signal processing components using calibrated test signals and document the performance of each radar system.

The following sections of this report describe results of calibration procedures developed and tested in 1975 for the NSSL Doppler radars. These techniques are part of the daily routine in preparing for severe storm surveillance. The material is provided as an aid to users in selection of data sets and in evaluation of meteorological inferences. It is intended as a tabulation of descriptive parameters, subjective evaluations and listing of known problems associated with the data listed in the Data Summary Log. It is not intended as a comprehensive discussion of parameters or techniques. For details, the reader is referred to one or more of the supplemental attachments or references.

Table 1 lists radar system characteristics utilized during the Spring Program and supercedes the preliminary table dated March 14, 1975. Note that some radar system characteristics are subject to variation and must be determined from the daily logs.

Tables 2 and 3 are tabulations of parameters pertaining to radar intensity calibration. Quantities listed in Table 3a are derived from the receiver calibrations made before and after data acquisition.

Table 4 tabulates noise introduced by the complex video digital quantization process based on measured ADC performance. The scheme used in this measurement is given in Section 2 (ADC Quantization - General Considerations in Quality Control Testing).

Spectrum image suppression level is tabulated by data set in Table 5. Values given for the Norman radar do not include the systematic high image at certain gates prior to May 27, 1975. This is discussed in Section 3 (Note on Norman Doppler Image Gates).

The noise level in the frequency domain, spectrum background level, is tabulated in Table 6. This quantity was estimated from scattergram values taken from spectra plots. Interpretation of this quantity is discussed in Section 4 (Note on Spectrum Background Noise Level).

Results of sun-scan orientation checks are given in Table 7.

A list of known data problems is in Table 8. This is not all inclusive, of course, since problems of a more subtle nature will probably be found during data analysis.

An example of a ranging check is given in Section 5 for both the Norman (NRO) and Cimarron (CIM) radars. An estimate of ranging uncertainty is also given in this discussion.

Section 6 contains the results of received power calibration check by sun flux density for both the Norman and Cimarron systems.

The measured standard deviation of intensity and velocity estimates are compared with theoretical values in Section 7.

TABLE 1a.

NSSL Doppler Radar Characteristics
June 25, 1975

| Parameter | Cimarron (CIM) | Norman (NRO) | Hi PRF (NRO) |
|---|---|---|---|
| **Antenna** | | | |
| Shape | Parabolic | Parabolic | Parabolic |
| Diameter | 9.15 m | 9.15 m | 9.15 m |
| Half-power Beam Width | 0.80 deg | 0.81 deg | 0.81 deg |
| Gain | 46 dB | 46.8 dB | 46.8 dB |
| First Side Lobe Level | 21 dB | 21 dB | 21 dB |
| Polarization | Horizontal | Vertical | Vertical |
| RMS Surface Deviation | 2.5 mm | 2.8 mm | 2.8 mm |
| **Transmitter** | | | |
| Wavelength | 10.97 cm | 10.52 cm | 10.52 cm |
| Frequency | 2735 MHz | 2850 MHz | 2850 MHz |
| Pulse Repetition Time | 768 μsec | 768 μsec | 288 μs |
| Pulse Width | 1 μsec (150 m) | 1 μsec (150 m) | 0.35 μs (52 m) |
| Peak Power* | 500 kw | 700 kw | 200 kw |
| **Receiver** | | | |
| System Noise Figure | 4.1 dB | 3.3 dB | 5 dB** |
| Transfer Function | Doppler-linear<br>Intensity-logarithmic | Doppler-linear<br>Intensity-logarithmic | Doppler-linear<br>Intensity-logarithmic |
| Dynamic Range | 70 dB | 70 dB | 70 dB |
| Bandwidth (6 dB) | 4.52 MHz | 2.88 MHz | 0.81 MHz*** |
| Intermediate Frequency | 30 MHz | 30 MHz | 30 MHz |
| Min. Detectable Signal (SNR=0 dB)* | -103 dBm | -106 dBm | -105 dBm |
| **Doppler Time Series Data Acquisition** | | | |
| No. of Simultaneous Range Gates | 16 | 16 | 6 |
| No. of 16-Gate Blocks Along Radial | Unlimited | 8 | 8 |
| Range Gate Spacing | 300, 350...1200, 1350m | 150, 300, 600, 1200m | 150, 300, 600, 1200m |
| Azimuthal Sample Spacing | 0.1 to 9.9 deg | 0.1 to 9.9 deg | 0.1 to 9.9 deg |
| Automatic Elevation Increment | 0.5 to 9.9 deg | 0.1 to 9.9 deg | 0.1 to 9.9 deg |
| Number of Samples in Time Series† | $2^n$<br>n=1, 2...13 | $2^n$<br>n=1, 2...13 | $2^n$<br>n=1, 2...13 |
| Complex Video Digital Word Length | 10 bits (binary) | 12 bits (binary) | 12 bits (binary) |
| **Intensity Data Acquisition** | | | |
| No. of Range Gates | 762 | 762 | 192 |
| Range Gate Spacing | 150 m | 150 m | 225 m |
| Number of Samples in Estimate†† | $2^n-1$<br>n=4...11 | $2^n-1$<br>n=4...11 | $2^n-1$<br>n=4...11 |
| Time Window Function†† | Linear or exponential | Linear or exponential | Linear or exponential |
| Intensity Estimate Word Length (Recorded) | 6 bits (binary) | 6 bits (binary) | 6 bits (binary) |
| **General Features** | | | |
| Azimuthal Antenna Rotation Rate | 0.1 to 24.0 deg $sec^{-1}$ | 0.1 to 10 deg $sec^{-1}$ | 0.1 to 10 deg $sec^{-1}$ |
| Maximum Unambiguous Range | 115 km | 115 km | 43 km |
| Maximum Unambiguous Velocity | $\pm$ 35.6 m $sec^{-1}$ | $\pm$ 34.2 m $sec^{-1}$ | $\pm$ 91 m $sec^{-1}$ |
| PPI Capability | Yes | Yes | Yes |
| RHI Capability | Yes | Yes | Yes |
| Coplane Capability | No | No | No |

* Representative value: see Table 2 or daily log for particular data set.

** 8 dB before May 22, 1975

*** 2.03 MHz before May 22, 1975

† Most data taken with N=64 for normal PRF and N=128 for Hi PRF.

†† Practically all data taken with Ns=127 and exponential time window.

TABLE 1b.

Calibration and Timing Parameters
June 25, 1975

| Parameter | Cimarron (CIM) | Norman (NRO) | Hi PRF (NRO) |
|---|---|---|---|
| Radome Loss (two way) | 2.0 dB | 2.0 dB | 2.0 dB |
| Coupler Loss | 36.5 dB | 36.2 dB | 36.2 dB |
| Cable Loss | 6.7 dB | 9.5 dB | 9.5 dB |
| Waveguide Loss (two way) | 3.6 dB | 2.0 dB | 2.0 dB |
| Receiver Detection Loss | 0.43 dB | .69 dB | 6.81 dB* |
| Delay to Tx Pulse | 4.4 μs | 4.0 μs | 4.4 μs |
| Doppler Sample-Hold Aperture | 0.07 μs | 0.4 μs | 0.4 μs |
| Integrator Start Delay | 4.2 μs | 3.7 μs | 4.0 μs |
| Integrator Spacing | 1.0 μs | 1.0 μs | 1.5 μs |
| Receiver Rise Time | .22 μs | .35 μs | 1.67 μs† |
| Receiver Initial Delay | 0.1 μs | 0.1 μs | 0.1 μs |
| Plumbing Delay | 0.33 μs | 0.1 μs | 0.1 μs |

* Loss was 3.31 dB prior to May 22, 1975.

† .37 μs before May 22, 1975.

TABLE 2

RADAR PEAK POWER MEASUREMENTS

| Date | Cimarron (CIM) | Norman (NRO) "A" | Norman (NRO) "B" (Hi PRF) |
|---|---|---|---|
| 5-13-75 | * | 683 kw | 217 kw |
| 5-19-75 | | 470 kw | 216 kw |
| 5-22-75 | | 450 kw | 220 kw |
| 5-24-75 | | 730 kw | |
| 5-26-75 | | 730 kw | |
| 5-28-75 | | 730 kw | |
| 5-29-75 | | 730 kw | |
| 6-02-75 | | 718 kw | 195 kw |
| 6-04-75 | | 718 kw | |
| 6-05-75 | | 706 kw | |
| 6-06-75 | | 706 kw | |
| 6-08-75 | | 730 kw | 220 kw |
| 6-11-75 | | 740 kw | |
| 6-13-75 | | 706 kw | |

* Maintained 500 kw during periods of data collection.

TABLE 3a

Logarithmic Receiver Noise Level and Logging Constant

| Date | Norman (NRO) | | Cimarron (CIM) | |
|---|---|---|---|---|
| 5-19-75 | -107.3 dBm | 0.62 AGC/dB | | |
| 5-22-75 | -103.0 dBm | 0.64 AGC/dB | -100.7 dBm | 0.76 AGC/dB |
| 5-24-75 | -107.4 dBm | 0.62 AGC/dB | - 97.3 dBm | 0.86 AGC/dB |
| 5-26-75 | -105.2 dBm | 0.62 AGC/dB | -103.3 dBm | 0.78 AGC/dB |
| 5-29-75 | -102.3 dBm | 0.62 AGC/dB | -101.0 dBm | 0.76 AGC/dB |
| 6-05-75 | -105.0 dBm | 0.64 AGC/dB | - 98.0 dBm | 0.83 AGC/dB |
| 6-08-75 | -102.1 dBm | 0.65 AGC/dB | -102.6 dBm | 0.88 AGC/dB |
| 6-09-75 | | | - 98.2 dBm | 0.80 AGC/dB |
| 6-13-75 | -106.7 dBm | 0.71 AGC/dB | -100.9 dBm | 0.82 AGC/dB |

TABLE 3b

Magnitude of Intensity Calibration Drift

| Date | Norman (NRO) | Cimarron (CIM) |
|---|---|---|
| 5-19-75 | <0.3 dB | Malfunction |
| 5-22-75 | <1.0 dB | 1 to 5 dB |
| 5-24-75 | <0.1 dB | Unknown |
| 5-26-75 | <0.5 dB | 0 to 3 dB |
| 5-29-75 | <0.8 dB | 1 to 5 dB |
| 6-05-75 | 2 to 4 dB | Unknown |
| 6-08-75 | 3 to 4 dB | 3 to 5 dB |
| 6-09-75 | —— • —— | Unknown |
| 6-13-75 | <0.5 dB | 0.5 dB |

TABLE 4

Signal to ADC Quantization Noise Ratio

| Date | Norman (NRO) | Cimarron (CIM) |
|---|---|---|
| 5-19-75 | >45 dB | >35 dB |
| 5-22-75 | >45 dB | >35 dB |
| 5-24-75 | >45 dB | >35 dB |
| 5-26-75 | >45 dB | >35 dB |
| 5-29-75 | >45 dB | >40 dB |
| 6-05-75 | >45 dB | >35 dB |
| 6-08-75 | >45 dB | >40 dB |
| 6-09-75 | —·— | >40 dB |
| 6-13-75 | >45 dB | >35 dB |

TABLE 5

Spectrum Image Suppression*

| Date | Norman (NRO) | Cimarron (CIM) |
|---|---|---|
| 5-19-75 | >20 dB | |
| 5-22-75 | >20 dB | ~10 dB |
| 5-24-75 | >15 dB | ~15 dB |
| 5-26-75 | >20 dB | ~15 dB |
| 5-29-75 | >15 dB | ~15 dB |
| 6-05-75 | >15 dB | >15 dB |
| 6-08-75 | >15 dB | ~15 dB |
| 6-09-75 | —·— | |
| 6-13-75 | >15 dB | >15 dB |

*This does not include the systematic image at certain gates of the Norman radar (see Note on Image Gates).

TABLE 6

Spectrum Background Level (dB below Signal Mode)*

| Date | Norman (NRO) | Cimarron (CIM) |
|---|---|---|
| 5-19-75 | 35 dB | |
| 5-22-75 | 30 dB | 25 dB |
| 5-24-75 | 30 dB | 20 dB |
| 5-26-75 | 35 dB | 22.5 dB |
| 5-29-75 | 27.5 dB | 27.5 dB |
| 6-05-75 | 30 dB | 25 dB |
| 6-08-75 | 35 dB | 20 dB |
| 6-09-75 | —·— | 20 dB |
| 6-13-75 | 32.5 dB | 30 dB |

* The value given is an estimate at a SNR = 20 dB and serves only as a qualitative index. For a more comprehensive discussion see Note on Spectrum Background Noise Level.

TABLE 7

Antenna Orientation Checks (Sun Scans)

| Site | Date | Deviation | |
|---|---|---|---|
| | | Azimuth | Elevation |
| Norman (NRO) | 8 May 1975 | .07° ccw | .01° low |
| | 3 June 1975 | —·— | .16° low |
| | 25 June 1975 | 0 | .64° low |
| | 16 July 1975 | .30° cw | .71° low |
| Cimarron (CIM) | 8 May 1975 | .01° cw | .09° high |
| | 25 June 1975 | .16° cw | .15° high |
| | 16 July 1975 | .06° ccw | .16° high |

TABLE 8

Malfunctions, Glitches, and other Pesty Things

| Date | Norman (NRO) | Cimarron (CIM) |
|---|---|---|
| 5-19-75 | | 1. Intensity record malfunction - data recovery not feasible. Velocity data recovery possible by special processing. |
| 5-22-75 | 1. Gate 8 of header intensity has intermittent 1 bit. | 1. Gate 16 of header intensity has intermittent 8 bit.* |
| 5-24-75 | 1. Gate 8 of header intensity has intermittent 1 bit. | 1. Gate 16 of header intensity has intermittent 8 bit.*<br>2. Complex video clipping at SNR ≈ 30 dB.* |
| 5-26-75 | 1. Gate 8 of header intensity has intermittent 1 bit.<br>2. Complex video clipping at SNR≈50 dB. | 1. Gate 16 of header intensity has intermittent 8 bit.* |
| 5-29-76 | 1. Gate 8 of header intensity has intermittent 1 bit. | 1. Gate 16 of header intensity has intermittent 8 bit.* |
| 6-05-75 | 1. Gate 8 of header intensity has intermittent 1 bit. | 1. Intensity record malfunction. Data not recoverable. Doppler header intensity valid.*<br>2. Gate 16 header intensity has intermittent 8 bit. |
| 6-08-75 | 1. Gate 8 of header intensity has intermittent 1 bit. | 1. Complex video clipping.* |
| 6-09-75 | 1. No data taken. | 1. Header intensity values are shifted by one gate.* |
| 6-13-75 | 1. No velocity data from 1803 CST to 1900 CST, Tapes DP7571 through DP7574, Intensity data valid. | 1. Header intensity values are shifted by one gate.<br>2. Gate 6 of header intensity has intermittent 2 bit. |

* All data sets have header intensity values shifted by one gate; location 1 is gate 2, location 2 is gate 3, etc..., location 16 is gate 1.

General Hardware Problems:

1. NRO actual antenna speed varies significantly from specified value.
2. No antenna speed parameter in CIM housekeeping.
3. CIM complex video contains intermittent noise. (See Section 4.)

1975 CIMMARON DOPPLER COLLECTION LOG

| TAPE | DATE | START TIME | STOP TIME | START AZM | STOP AZM | TILT |
|---|---|---|---|---|---|---|
| CP7503 | 051975 | 144459 | 145154 | 179 | 210 | 04.1 |
| CP7504 | 051975 | 154659 | 154928 | 174 | 179 | 04.1 |
| CP7505 | 051975 | 160808 | 161009 | 179 | 215 | 05.1 |
| CP7505 | 051975 | 161252 | 161538 | 179 | 220 | 07.1 |
| CP7506 | 051975 | 185820 | 190110 | 209 | 240 | 10.1 |
| CP7506 | 051975 | 190441 | 190745 | 199 | 240 | 08.1 |
| CP7507 | 051975 | 191525 | 192132 | 189 | 240 | 09.1 |
| CP7508 | 051975 | 192839 | 193409 | 184 | 240 | 08.1 |
| CP7509 | 051975 | 200439 | 200659 | 158 | 241 | 06.1 |
| CP7510 | 052275 | 145255 | 145901 | 249 | 300 | 20.1 |
| CP7511 | 052275 | 153549 | 153640 | 221 | 265 | 11.1 |
| CP7511 | 052275 | 154709 | 155114 | 221 | 265 | 11.1 |
| CP7512 | 052275 | 155906 | 160519 | 221 | 265 | 12.1 |
| CP7513 | 052275 | 160942 | 161414 | 224 | 270 | 11.1 |
| CP7514 | 052275 | 162255 | 163008 | 239 | 290 | 16.1 |
| CP7515 | 052275 | 173337 | 173824 | | | . |
| CP7516 | 052275 | 101159 | 103108 | 068 | 074 | 01.0 |
| CP7519 | 052475 | 114951 | 115606 | 049 | 060 | 02.3 |
| CP7519 | 052475 | 120052 | 120123 | 049 | 060 | 02.5 |
| CP7519 | 052475 | 121703 | 121814 | 114 | 135 | 02.6 |
| CP7519 | 052475 | 122233 | 122630 | 114 | 135 | 02.5 |
| CP7521 | 052675 | 105520 | 105600 | 119 | 135 | 02.1 |
| CP7523 | 052675 | 135134 | 135513 | 040 | 070 | 03.5 |
| CP7523 | 052675 | 135557 | 135718 | 037 | 070 | 01.5 |
| CP7524 | 052675 | 140149 | 140629 | 040 | 070 | 03.5 |
| CP7528 | 052975 | 154915 | 155102 | 244 | 275 | 03.6 |
| CP7528 | 052975 | 155224 | 155403 | 244 | 275 | 03.1 |
| CP7529 | 052975 | 155759 | 160050 | 249 | 270 | 03.1 |
| CP7529 | 052975 | 160116 | 160226 | 249 | 270 | 03.1 |
| CP7529 | 052975 | 160248 | 160330 | 249 | 270 | 02.1 |
| CP7532 | 060575 | 173650 | 174059 | 329 | 345 | 11.3 |
| CP7533 | 060575 | 174604 | 175007 | 329 | 350 | 12.0 |
| CP7534 | 060575 | 180144 | 180521 | 334 | 355 | 10.0 |
| CP7535 | 060575 | 182039 | 182446 | 334 | 355 | 12.0 |
| CP7536 | 060575 | 184504 | 184914 | 334 | 000 | 09.0 |
| CP7537 | 060575 | 190302 | 190716 | 334 | 010 | 07.0 |
| CP7538 | 060575 | 192044 | 192411 | 339 | 015 | 05.0 |
| CP7540 | 060875 | 160829 | 161048 | 294 | 320 | 04.0 |
| CP7540 | 060875 | 161238 | 161441 | 294 | 320 | 02.0 |
| CP7541 | 060875 | 162605 | 162841 | 295 | 320 | 03.0 |
| CP7541 | 060875 | 162935 | 163250 | 295 | 320 | 03.4 |
| CP7542 | 060875 | 164022 | 164337 | 295 | 320 | 03.4 |
| CP7542 | 060875 | 164827 | 165124 | 295 | 320 | 03.5 |
| CP7543 | 060875 | 165727 | 170314 | 310 | 330 | 09.0 |
| CP7544 | 060875 | 171146 | 171743 | 310 | 330 | 09.0 |
| CP7545 | 060875 | 173322 | 173636 | 314 | 335 | 09.1 |
| CP7545 | 060875 | 173713 | 173953 | 314 | 335 | 07.0 |

| TAPE | DATE | START TIME | STOP TIME | START AZM | STOP AZM | TILT |
|---|---|---|---|---|---|---|
| CP7546 | 060875 | 190555 | 191149 | 214 | 245 | 19.0 |
| CP7547 | 060875 | 191737 | 192407 | 204 | 245 | 17.1 |
| CP7548 | 060875 | 193329 | 194054 | 179 | 235 | 15.1 |
| CP7549 | 060875 | 201319 | 201901 | 139 | 190 | 19.4 |
| CP7550 | 060875 | 203008 | 203325 | 029 | 050 | 13.0 |
| CP7550 | 060875 | 204233 | 204459 | 029 | 050 | 13.0 |
| CP7552 | 061375 | 134723 | 134920 | 359 | 030 | 8.6 |
| CP7552 | 061375 | 135054 | 135252 | 359 | 030 | 9.5 |
| CP7553 | 061375 | 135952 | 140348 | 009 | 040 | 12.0 |
| CP7553 | 061375 | 140625 | 140808 | 014 | 040 | 09.1 |
| CP7554 | 061375 | 142553 | 142856 | 024 | 055 | 11.0 |
| CP7554 | 061375 | 143209 | 143426 | 024 | 055 | 08.0 |
| CP7555 | 061375 | 144105 | 144342 | 024 | 055 | 10.1 |
| CP7555 | 061375 | 145016 | 145337 | 029 | 060 | 06.1 |
| CP7556 | 061375 | 145844 | 150439 | 030 | 060 | 07.5 |
| CP7557 | 061375 | 175207 | 175702 | 035 | 060 | 05.5 |
| CP7558 | 061375 | 180319 | 180815 | 035 | 060 | 05.5 |
| CP7559 | 061375 | 181604 | 181940 | 024 | 075 | 03.1 |
| CP7560 | 061375 | 182641 | 183133 | 024 | 075 | 10.1 |
| CP7561 | 061375 | 183833 | 184307 | 029 | 060 | 13.1 |
| CP7562 | 061375 | 185022 | 185451 | 029 | 060 | 13.1 |
| CP7563 | 061375 | 190052 | 190404 | 034 | 070 | 12.2 |
| CP7563 | 061375 | 190617 | 190718 | 034 | 080 | 03.1 |
| CP7564 | 061375 | 192319 | 192719 | 034 | 085 | 09.1 |
| CP7565 | 061375 | 193604 | 194006 | 034 | 085 | 09.1 |
| CP7566 | 061375 | 195745 | 200237 | 059 | 100 | 13.1 |
| CP7567 | 061375 | 203949 | 204504 | 358 | 096 | 16.2 |
| CP7567 | 061375 | 205033 | 205507 | 059 | 100 | 05.1 |
| CP7568 | 061375 | 210447 | 210917 | 064 | 110 | 14.0 |
| CP7569 | 061375 | 211906 | 212211 | 079 | 115 | 12.0 |
| CP7570 | 060975 | 182719 | 183047 | 267 | 330 | 01.0 |
| CP7570 | 060975 | 183306 | 184740 | 267 | 330 | 01.0 |

1975 NORMAN DOPPLER COLLECTION LOG

| TAPE | DATE | START TIME | STOP TIME | START AZM | STOP AZM | TILT |
|---|---|---|---|---|---|---|
| DP7503 | 051975 | 144458 | 145018 | 249 | 280 | 06.1 |
| DP7504 | 051975 | 154703 | 155147 | 229 | 260 | 05.0 |
| DP7504 | 051975 | 155257 | 155447 | 229 | 260 | 05.1 |
| DP7505 | 051975 | 160810 | 161106 | 239 | 270 | 08.0 |
| DP7505 | 051975 | 161259 | 161640 | 239 | 280 | 07.0 |
| DP7506 | 051975 | 182500 | 182627 | 239 | 270 | 06.4 |
| DP7506 | 051975 | 184411 | 184641 | 239 | 270 | 06.4 |
| DP7506 | 051975 | 185822 | 190138 | 239 | 270 | 08.0 |
| DP7506 | 051975 | 190451 | 190729 | 239 | 270 | 06.0 |
| DP7507 | 051975 | 191522 | 191631 | 229 | 270 | 02.0 |
| DP7507 | 051975 | 191727 | 192131 | 229 | 270 | 09.0 |
| DP7508 | 051975 | 192841 | 193246 | 229 | 270 | 09.0 |
| DP7509 | 051975 | 200359 | 201020 | 219 | 270 | 07.0 |
| DP7510 | 052275 | 134029 | 134043 | 254 | 283 | 01.0 |
| DP7510 | 052275 | 140421 | 141226 | 259 | 280 | 02.5 |
| DP7511 | 052275 | 141603 | 142030 | 259 | 280 | 02.5 |
| DP7511 | 052275 | 142248 | 142625 | 259 | 280 | 02.5 |
| DP7512 | 052275 | 143204 | 144011 | 259 | 280 | 02.5 |
| DP7513 | 052275 | 154717 | 155359 | 239 | 280 | 05.0 |
| DP7514 | 052275 | 171545 | 172555 | 189 | 210 | 08.1 |
| DP7515 | 052275 | 173029 | 173813 | 189 | 210 | 10.0 |
| DP7516 | 052275 | 174540 | 175409 | 189 | 220 | 12.1 |
| DP7516 | 052275 | 175500 | 175636 | 189 | 220 | 01.1 |
| DP7520 | 052475 | 123951 | 124246 | 049 | 070 | 02.0 |
| DP7521 | 052475 | 151212 | 151435 | 289 | 310 | 02.0 |
| DP7521 | 052475 | 151810 | 152035 | 289 | 310 | 02.0 |
| DP7521 | 052475 | 152342 | 152621 | 289 | 310 | 02.0 |
| DP7522 | 052475 | 153501 | 153858 | 299 | 320 | 02.0 |
| DP7522 | 052475 | 154231 | 154628 | 299 | 320 | 02.0 |
| DP7523 | 052475 | 160529 | 160702 | 169 | 200 | 08.1 |
| DP7523 | 052475 | 160809 | 160942 | 169 | 200 | 08.1 |
| DP7526 | 052675 | 111526 | 112149 | 109 | 140 | 01.5 |
| DP7527 | 052675 | 135140 | 135636 | 009 | 050 | 02.8 |
| DP7528 | 052675 | 140140 | 140500 | 009 | 050 | 04.0 |
| DP7529 | 052675 | 153455 | 154413 | 129 | 160 | 05.1 |
| DP7530 | 052675 | 154756 | 155431 | 129 | 160 | 06.1 |
| DP7531 | 052675 | 160055 | 160733 | 139 | 170 | 06.6 |
| DP7537 | 052975 | 151631 | 152326 | 259 | 290 | 01.5 |
| DP7537 | 052975 | 152622 | 153039 | 259 | 290 | 01.5 |
| DP7538 | 052975 | 153331 | 153540 | 259 | 290 | 01.5 |
| DP7538 | 052975 | 153618 | 153948 | 269 | 300 | 01.5 |
| DP7540 | 052975 | 184532 | 185202 | 280 | 338 | 09.9 |
| DP7541 | 052975 | 190506 | 190846 | 330 | 019 | 27.8 |
| DP7541 | 052975 | 191049 | 191224 | 330 | 048 | 13.9 |
| DP7542 | 052975 | 195116 | 201745 | 219 | 300 | 04.9 |
| DP7543 | 052975 | 203104 | 203614 | 049 | 096 | 05.1 |

| TAPE | DATE | START TIME | STOP TIME | START AZM | STOP AZM | TILT |
|---|---|---|---|---|---|---|
| DP7544 | 052975 | 205110 | 210118 | 049 | 096 | 05.1 |
| DP7548 | 060575 | 172707 | 173246 | 029 | 070 | 03.1 |
| DP7549 | 060575 | 182033 | 182958 | 309 | 340 | 06.1 |
| DP7550 | 060575 | 184502 | 185124 | 319 | 340 | 08.1 |
| DP7551 | 060575 | 190302 | 190934 | 319 | 350 | 06.1 |
| DP7552 | 060575 | 192047 | 192531 | 329 | 359 | 06.5 |
| DP7555 | 060875 | 135919 | 140819 | 209 | 230 | 01.6 |
| DP7556 | 060875 | 144512 | 150956 | 289 | 320 | 03.0 |
| DP7557 | 060875 | 151404 | 153642 | 289 | 320 | 03.0 |
| DP7558 | 060875 | 154221 | 154358 | 289 | 320 | 01.6 |
| DP7558 | 060875 | 155258 | 155438 | 289 | 320 | 01.5 |
| DP7558 | 060875 | 160711 | 161005 | 289 | 320 | 05.0 |
| DP7559 | 060875 | 161344 | 162120 | 309 | 320 | 04.1 |
| DP7560 | 060875 | 190702 | 191018 | 259 | 290 | 09.0 |
| DP7560 | 060875 | 191847 | 192156 | 269 | 290 | 10.1 |
| DP7561 | 060875 | 193441 | 194157 | 259 | 300 | 15.0 |
| DP7562 | 060875 | 201428 | 202257 | 239 | 300 | 19.6 |
| DP7563 | 060875 | 203115 | 203351 | 339 | 359 | 05.0 |
| DP7563 | 060875 | 204341 | 204515 | 339 | 359 | 05.0 |
| DP7565 | 061375 | 142420 | 143207 | 009 | 030 | 05.0 |
| DP7566 | 061375 | 144106 | 144749 | 003 | 030 | 05.5 |
| DP7567 | 061375 | 145856 | 150447 | 009 | 030 | 08.1 |
| DP7568 | 061375 | 151706 | 152150 | 029 | 050 | 06.1 |
| DP7569 | 061375 | 174155 | 174905 | 009 | 040 | 05.1 |
| DP7570 | 061375 | 175215 | 175838 | 009 | 040 | 06.0 |
| DP7571 | 061375 | 180321 | 181020 | 019 | 040 | 09.0 |
| DP7572 | 061375 | 181610 | 182320 | 019 | 050 | 10.0 |
| DP7573 | 061375 | 182653 | 183320 | 009 | 050 | 07.0 |
| DP7574 | 061375 | 183835 | 184145 | 009 | 030 | 05.1 |
| DP7575 | 061375 | 190105 | 191233 | 009 | 050 | 11.0 |
| DP7576 | 061375 | 192321 | 193345 | 019 | 060 | 12.1 |
| DP7577 | 061375 | 193556 | 194542 | 029 | 070 | 12.1 |
| DP7578 | 061375 | 195746 | 200442 | 339 | 359 | 16.1 |
| DP7579 | 061375 | 201232 | 201940 | 039 | 080 | 07.0 |
| DP7580 | 061375 | 203954 | 204505 | 009 | 120 | 09.1 |
| DP7581 | 061375 | 205330 | 205850 | 019 | 070 | 14.1 |
| DP7582 | 061375 | 210448 | 210954 | 029 | 090 | 12.1 |
| DP7583 | 061375 | 211900 | 212404 | 039 | 100 | 12.1 |
| DP7584 | 061375 | 213913 | 214357 | 049 | 110 | 11.1 |

## MAY 1975 DOPPLER ( RAW DATA )

TOTAL MINUTES OF DIGITAL DATA

N-NORMAN C-CIMARRON H-HIGH PRF

| DATE \ HOUR | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | | | | | | | | | | | | | | | |
| 19 | | | | | | 5N<br>7C | 7N<br>2C | 7N<br>5C | | 6N<br>2C | 15N<br>16C | 6N<br>2C | | | |
| 20 | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | |
| 22 | | 19C | | | 1N | 24N<br>6C | 7N<br>6C | 16C | 28NH<br>4C | | | | | | |
| 23 | | | | | | | | | | | | | | | |
| 24 | | | | 3N | | | 15N | 4N | | | | | | | |
| 25 | | | 6C | 5C | | | | | | | | | | | |
| 26 | | 1C | 7N | | 5N<br>4C | 3N<br>4C | 16N | 7N | | | | | | | |
| 27 | | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | | | |
| 29 | | | | | | | 17N<br>6C | 3C | | 6NH | 14NH | 32NH | 1N | | |
| 30 | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | |

## JUNE 1975 DOPPLER ( RAW DATA )

TOTAL MINUTES OF DIGITAL DATA

N-NORMAN C-CIMARRON H-HIGH PRF

| DATE \ HOUR | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | | | 6N<br>8C | 15N<br>11C | 12N<br>7C | | | | |
| 6 | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | |
| 8 | | 1N | 23N | 37N | 10NH<br>21C | 16C | | 13N<br>20C | 13N<br>11C | | | |
| 9 | | | | | | | | | | | | |
| 10 | | | | | | | 19C | | | | | |
| 11 | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 13 | | 4C | 16N<br>19C | 10N<br>5C | | 14N<br>5C | 23N<br>23C | 35N<br>14C | 22N<br>12C | 15N<br>7C | | |
| 14 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |

## SECTION 1

### Digital Integrator Calibration - General Considerations in Quality Control Testing

The logarithmic receiver-digital integrator calibration is given in detail in Sirmans and Barclay (1973), Sirmans and Doviak (1973), and Sirmans (1974a). What follows is a summary of the technique as well as an abbreviated discussion of statistical considerations and noise measurements (Sirmans, 1974b).

#### Procedure

Digital integrator calibration is a three-step procedure:

1. The boundaries of input quantization categories (i.e., the ADC classes) are measured by injecting a known signal level into the receiver.

2. An incremental integration is performed (increments are input digital categories) on the theoretical probability density of a meteorological signal having a specified mean power. The relative frequency of occurrence of digital classes thus obtained are assigned digital class weights (at the ADC ouput), and the mean of these weights is the digital output corresponding to the specified input mean power.

3. The entire receiver input power-digital integrator output transfer characteristic is then determined by "lagging" the theoretical mean input power through the dynamic range of the receiver. Thus, the calibration gives a mean input power versus the corresponding digital output. Difference between calibration (signal generator) power corresponding to given digital output and theoretical input power of a meteorological signal corresponding to this digital output is termed bias which is corrected by the calibration procedure.

This bias is a composite of the probability density effect, the receiver transformation, and the quantization by truncation. Note that in the logarithmic region of receiver response the bias is 2.5 dB plus 1/2 of the input quantization increment (Sirmans and Barclay, 1973). Bias increases near the upper extreme due to saturation and decreases near the lower extreme due to the additive noise effect.

#### Statistics of the Calibration

The technique contains two major sources of error (other than the human element): (1) the quantization boundary uncertainty, and (2) the signal source accuracy. We will examine the boundary uncertainty first. Normally, the "logging constant" of digital output-input power transfer is about 1.25 dB/digit, thus the quantization width (one least significant digit) is larger

than input signal increment (1 dB = .8 digit) and the S.D. of the digital boundaries is just the quantization S.D.

Since the quantization standard error

$$\sigma_B = \frac{1}{2\sqrt{3}} = .29 \text{ digits} \tag{1}$$

is small compared to the standard rms error of the input weather signal, 4.46 digits, we may assume the error of derived relative frequency of occurrence, i.e., the increment integral of theoretical probability density (over the class) is linearly related to the width of the class. Since width of the class has a variance twice that of either boundary (statistically independent boundaries)(Lee, 1964), we find the variance of the calibration estimate to be:

$$\sigma^2 = 2\sigma_B^2 = \frac{1}{6} \text{ digits}^2 = (.41)^2 \text{ digit}^2 \tag{2}$$

or a standard deviation of about 0.5 dB for the usual transfer characteristic.

Signal source will also constitute an uncertainty since no real source is purely deterministic. This uncertainty, however, is more in the form of a bias rather than a variance since the mechanism is an inability to control exact power injected into the system and is largely repeatable and consistent from run to run. Absolute accuracy of most sources is about ± 2 dB and it can be improved to 1 percent by comparing the source against a power meter at the higher input power levels (>-20 dBm). Unfortunately, the source cannot be calibrated over the entire dynamic range of the receiver due to power meter limitation. "Tracking accuracy" of the signal source used (i.e., the dB difference between true output power and power indicated by the dial) is about ± 1 dB and should be entered in the daily calibration log.

Besides providing measurement standards, the calibration listing can serve to monitor performance of the hardware. For example, the 1 dB increment should be a continuum on the digital scale, i.e., the digital output should vary in steps of about one. Calibration points should fit a smooth regression line, not necessarily straight but without abrupt changes or discontinuities. Histograms of the output variable should reflect these properties.

## Logarithmic Receiver Noise Power Determination

Determination of receiver noise power is necessary for certain studies requiring a signal-to-noise ratio, total variance of the signal plus noise power estimate or specification of detectable signal level. Noise power can be measured directly although it is not done routinely for any of the NSSL radars since this quantity has no meteorological significance. Instead, the following graphic technique of estimating noise power from the response characteristic of the logarthmic receiver-digital integrator is offered.

Integrator output values, D, of a logarithmic receiver are related to the total meteorological signal plus noise power $P_T = P_s + P_N$ by

$$D = \alpha\ 10 \log_{10} [\frac{P_T}{P_{ref}}] + K \tag{3}$$

where $\alpha$ is the "logging constant", K is the offset of digital intercept value, $P_{ref}$ is the reference power, ($P_{ref} = 10^{-3}$ watts for power in dBm). The logging constant, $\alpha$ , may be determined by selecting a region of logarithmic response where $P_S >> P_N$, and calculating the slope

$$\alpha \simeq \Delta[D]/\Delta[10 \log \frac{P_S}{P_{ref}}] \tag{4}$$

Transfer characteristic of this logarithmic segment of the response may be expressed as

$$D_\ell = \alpha\ (10 \log_{10} \frac{P_S}{P_1}) \tag{5}$$

where $P_1$ is the input power intercept value at D = 0 (see fig. 1). To determine the noise power from the receiver calibration with a known signal power, it is necessary to establish a relationship between the digital output of known signal plus unknown noise power. There are two convenient graphic methods. One method is based on a calibration curve using weather type signals by simply noting that the digital output and thus, the calibration signal input power corresponding to a signal-to-noise power ratio of unity is given by

$$D = \alpha\ [10 \log_{10} \frac{2P_N}{P_{ref}}] + K = 3\alpha + \alpha[10 \log_{10} \frac{P_N}{P_{ref}}] + K \tag{6}$$

at $\quad P_S = P_N$

or at the $(D,P_S)$ value which is 3 logging constants (if $\alpha$ is in digits/dB) above the D (intercept) corresponding to $P_S << P_N$ (intercept with the ordinate on fig. 1).

A second method can be devised by making the following assumptions:

1. The calibration signal source has an output power standard deviation small compared to the digital integrator quantization increment.

2. The noise amplitude probability density (in our case we assume Gaussian statistics) is the same as that of a meteorological signal.

The first assumption stipulates the only bias in the calibration signal power estimate to be due to quantization by truncation. The second stipulates that the bias of the noise power estimate is 2.5 dB plus the truncation bias. We may then determine input signal power corresponding to unity signal-to-noise ratio at the intercept of the logarithmic transfer and a D which is 2.5 logging constants above the D corresponding to $P_S \ll P_N$. (This 2.5 dB is bias of the noise power estimate due to its probability density.)

These two methods are illustrated in Figure 1 for the NRO radar. The two calibrations of Figure 1 also show the techniques are not sensitive to the offset or digital intercept value so long as the noise is not "thresholded" below digital two.

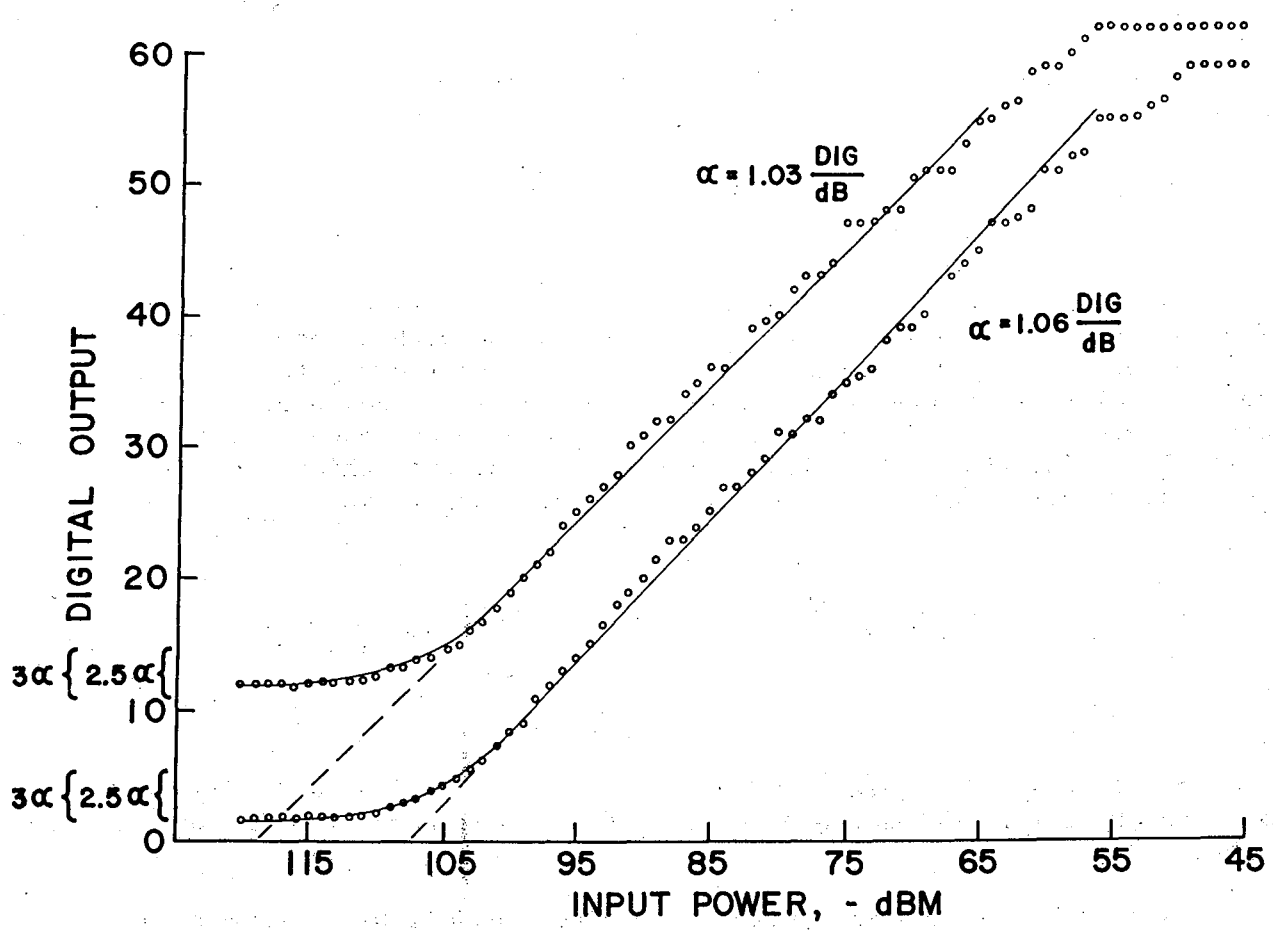



Figure 1. Transfer function from the receiver input to the output of a digital integrator.

## SECTION 2

### ADC Quantization - General Considerations In Quality Control Testing

Two parameters of analog to digital conversion (ADC) are of primary importance in data quality control checks. These are: (1) "differential linearity," which is the variation of actual class widths from the ideal width (1 LSB), usually given as ± 1/2 LSB, and (2) "conversion linearity," which is the deviation of class midpoints from a linear input-output conversion, usually given as about ± 1 LSB. A differential linearity of ± 1/2 LSB merely implies a ratio of maximum class width to minimum class width of three. A conversion linearity of ± 1 LSB requires that maximum deviation of any category from a linear conversion is not more than one ideal category width.

To measure the differential linearity, a test signal having a uniform distribution across the conversion range is injected and a "large number" of conversions are made to insure a statistically significant sample. The ratio of number of occurrences in a given class to the total in all classes is then a measure of the fractional width (fraction of conversion range) of that class. The listing of the number of occurrences in each class is the ADC histogram. Statistical parameters of ADC, as reflected in the histogram, can be developed as follows:

Let i be the index of the digital output number of a b bit converter, i.e., $i = 0, 1, 2, \ldots, 2^b - 2, 2^b - 1$ (for a 10 bit converter $i = 0, 1, 2, \ldots, 1022, 1023$). Let $N_i$ be the number of occurrences of the ith digit.

For the uniform input variable, the expected number of entries for classes having the ideal width (1 LSB) is

$$\overline{N} = \frac{1}{2^b} \sum_{i=0}^{2^b-1} N_i = \frac{1}{2^b} N_T \tag{7}$$

where $N_T$ = total number of samples; the ratio

$$\Delta q_i = \frac{N_i}{N_T} \tag{8}$$

is an estimate of the $i^{th}$ fractional width.

Finally, the average width is

$$\widehat{\Delta q} = \frac{1}{M} \sum_{i=0}^{2^b-1} \frac{N_i}{N_T} = \frac{1}{M} \tag{9}$$

where M is the number of non-zero width entries.

Statistics associated with the estimated class width, $\widehat{\Delta q}$, can be found by noting that the number of occurrences in a given class is described by the binomial distribution (Burlington and May, 1958).

Let $P_i$ be the probability that the sample falls in the $i^{th}$ class

$$p_i \approx \frac{N_i}{N_T} \tag{10}$$

and $q_i$ the probability that the sample does not fall in the $i^{th}$ class

$$q_i \approx 1 - \frac{N_i}{N_T} \tag{11}$$

then the observed number of entries has a standard deviation of

$$\text{S.D. } [N_i] = [N_T \; p_i q_i]^{1/2} \tag{12}$$

Normalizing the S.D. by expected number of entries and substituting the estimates,

$$\frac{\text{S.D.}[N_i]}{N_i} = \frac{[N_T \; p_i q_i]^{1/2}}{N_T p_i} = \frac{[1 - \frac{N_i}{N_T}]^{1/2}}{N_i^{1/2}} \tag{13}$$

provides a convenient measure of the uncertainty associated with class width measurement. For example, for a 10 bit ADC a number of entries, $N_i$ greater than $5(10^2)$ and $N_T = 5(10^5)$, creates a fractional S.D. less than 5 percent of the measured value.

The class width, $\Delta q$, determines the uncertainty associated with analog to digital conversion and thus the "noise" generated by ADC process (Sirmans, 1971; Sirmans, 1974c; Bendat and Piersol, 1971). For the ideal case of equi-width classes, the "noise" power introduced by quantization $P_{Nq}$ (for the assumption of uniform probability across the class): and conversion of 0 to 1 is given by

$$P_{Nq} = \frac{(1/2^b)^2}{12} \tag{14}$$

With varying widths the uncertainty is different for each digital number but the total noise power is the summation of the noise power "per sample" in the same fashion as signal power is the summation of signal power per sample.

The statistics of the signal and noise may be developed as follows:

Let $\overline{X_i^2}$ = the expected mean square of the input for conversion in the $i^{th}$ class; $\varepsilon_i$ = the uncertainty associated with the conversion.

$$\text{prob } [\varepsilon_i] = \frac{1}{\Delta q_i} \qquad -\frac{\Delta q_i}{2} < \varepsilon < \frac{\Delta q_i}{2}$$
$$= 0 \qquad \text{otherwise} \tag{15}$$

The noise sample power generated by a conversion in the $i^{th}$ class is

$$P_{N_{q_i}} = \frac{(\Delta q_i)^2}{12} \tag{16}$$

and signal sample power for the $i^{th}$ class by

$$P_{S_i} = X_i^{\,2} \tag{17}$$

for K samples we find the signal and noise power

$$P_{S+N_q} = \frac{1}{K} \sum_{j=1}^{K} (X_j + \varepsilon_j)^2 = \overline{X^2} + \overline{\Delta q^2}/12 \tag{18}$$

since the signal and noise are uncorrelated, the parameter usually given is the signal to quantization noise ratio in dB, i.e.,

$$SNR_q = 20 \log_{10} \frac{X_{rms}}{\Delta q_{rms}/2\sqrt{3}}$$
$$= 10 \log_{10} \left[ \frac{12\ \overline{X^2}}{\overline{\Delta^2 q}} \right] \tag{19}$$

Note that the noise power depends on: (1) the particular classes involved in the conversion, and (2) the mean square width, $(\Delta q^2)$. We therefore define the "effective" quantization width as the rms of $\Delta q^2$:

$$[\overline{\Delta q^2}]^{1/2} = \left[ \frac{1}{M} \sum_{i=1}^{M} \left( \frac{N_i}{N_T} \right)^2 \right]^{1/2} \tag{20}$$

This width will specify quantization noise so long as the input signal is distributed over the entire conversion range.

An equivalent number of equi-width classes $N_e$ which would produce the same quantization noise as the measured widths can be found from the rms width:

$$N_e = \frac{1}{[\overline{\Delta q^2}]^{1/2}} \quad . \tag{21}$$

Thus, the increase in measured noise power over theoretical noise (Eq. 14) also serves as a measure of ADC performance and is the quantization noise factor adjustment

$$QNF = 20 \log_{10}\left(\frac{2^b}{N_e}\right) \tag{22}$$

needed to specify, for example, the signal spectrum mode to average quantization noise level in the frequency domain.

In practice, it may be necessary to calculate the quantization noise as a function of input signal rms for a specified amplitude (class) distribution. For quality control testing, a Gaussian density (truncated) is used with signal rms to conversion range ratios of about $10^{-2}$, $10^{-1}$, and $3(10^{-1})$. The quantities pertaining to quantization given in the routine ADC quality control listings are:

1. Number of entries in each digital class (listing), $N_i$.
2. Total number of entries - all classes, $N_T$.
3. Number of non-zero width classes, M.
4. The average number of class entries, $\overline{N_i}$.
5. The fractional width estimates - listing (percent of ideal width), $\Delta q_i/\Delta q$ .
6. Standard deviation of $N_i$.
7. RMS width, Eq. 20.
8. The quantization noise power for each class $(\Delta q_i)^2/12$.
9. The number of equi-width classes specified by the quantization noise, Eq. 21.
10. The increase of quantization noise power due to the measured widths over the theoretical noise of the ideal converter for the uniform amplitude density, Eq. 22.
11. A/D quantization noise level for a Gaussian amplitude density of simulated input signal with an ADC transfer generated by a computer using the result of step 5 above. (As a special option.)

Conversion linearity can be best checked experimentally. However, it may be calculated from the estimated differential linearity by "piecewise approximation". The difference between the line connecting the midpoints of the interval, $\Delta q_i$, to the origin and the corresponding line of the ideal ADC

$$X_L = X \tag{23}$$

is the conversion linearity of the $i^{th}$ category.

Statistics of conversion linearity will, of course, reflect the statistics of width estimates as well as the particular width configuration. The observed length of the $i^{th}$ conversion category is given by

$$D(\Delta q_i) = \sum_{\ell=0}^{i} (\Delta q_\ell) \ , \quad 0 \le i \le 2^b - 1 \ , \tag{24}$$

whereas the corresponding length for an ideal ADC is $DL_i = (i + 1/2)\ \Delta q$ so that the conversion linearity, $CL_i$ becomes:

$$\begin{aligned} CL_i &= (D_{L_i} - \frac{\Delta q}{2}) - [D(\Delta q_i) - \frac{\Delta q_i}{2}] \\ &= (i\Delta q) - [D(\Delta q_i) - \frac{\Delta q_i}{2}] \ . \end{aligned} \tag{25}$$

As mentioned earlier, this parameter, (CL) is usually specified as $\pm$ 1 LSB and if there were no uncertainty in the estimates of class width, the CL distribution would be truncated at $\pm$ 1 LSB or $\pm\ 1/2^b$. However, in practice the S.D. (approximately 4 percent) associated with the measured class widths will result in a continuum of the distribution and it is necessary to establish a statistical confidence on the conversion linearity measured. We use the 1 percent level for a Gaussian density as the level above which the CL is assumed to be due to hardware. For example, if

$$\left| CL_i \right| > \frac{1}{2^b} + (2.575)(.04)(\Delta q_i) \ , \tag{26}$$

the class linearity is not within $\pm$ 1 LSB.

Some parameters of the ADC in service at NRO are in Table 9 and for CIM in Table 10. A complete analysis is available from the quality control testing.

TABLE 10

| | Norman ADC Characteristics | Datel #11044 |
|---|---|---|
| 1. | Non-zero classes | 3065 |
| 2. | Number of equivalent bits based on non-zero classes | 11.582 |
| 3. | Equivalent quantization noise width | 2014 |
| 4. | Number of equivalent bits based on noise | 10.976 |
| 5. | Quantization noise increase over ideal 12 bit converter | 6.143 dB |

TABLE 11

| | Cimarron ADC Characteristics | I Com Lab #304074 | Q Com Lab #504152 |
|---|---|---|---|
| 1. | Non-zero classes | I 1022 | Q 1022 |
| 2. | Number of equivalent bits based on non-zero classes | I 9.997 | Q 9.997 |
| 3. | Equivalent quantization noise width | I 1015 | Q 1015 |
| 4. | Number of equivalent bits based on noise | I 9.987 | Q 9.987 |
| 5. | Quantization noise increase over ideal 10 bit converter | I .06 dB | Q .06 dB |

## SECTION 3

### Note on Norman Doppler Image Gates

Prior to May 27, 1975, there existed a logic error in the Norman Doppler signal recording scheme which resulted in unusually large "image" spectrum at certain gates under certain conditions. The problem was due to multiplexing logic which resulted in a shift of one component of the complex video signal by one pulse repetition time (PRT) causing a deviation from phase quadrature. This anomoly (i.e., the data shift) occurred consistently at prescribed gates for a given gate spacing and block step as shown in Table 12.

However, the appearance of an image depends not only on the shift being present, but also on the true velocity at the gate (fig. 2) since the time shift of one PRT causes a phase shift which is proportional to input signal frequency, and if the phase shift was not sufficient, an image did not appear. The hardware problem was corrected May 27, and data taken after this time does not contain this type "image".

TABLE 12

High Image Gates

| Gate Spacing | Gate | | | |
|---|---|---|---|---|
| | 150 m | 300 m | 600 m | 1200 m |
| Step | | | | |
| 0 | - | - | - | - |
| 1 | 1 | - | 2 | 4 |
| 2 | - | 2 | - | 7 |
| 3 | - | 3 | 5 | 10 |
| 4 | 2 | - | - | - |
| 5 | - | 4 | 8 | - |
| 6 | - | 5 | - | - |
| 7 | 3 | - | 11 | - |

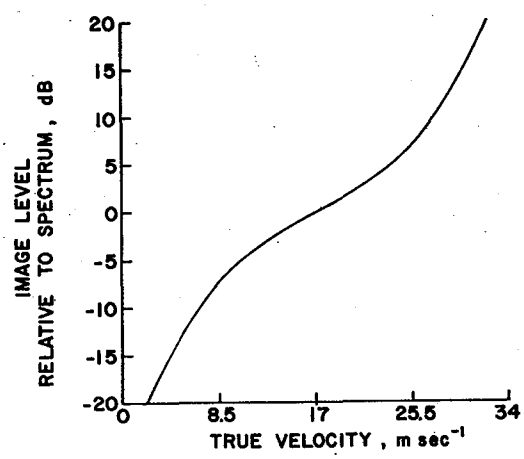



Figure 2. Image level of anomalous gates versus input velocity.

## SECTION 4

### Note on Spectrum Background Noise Level

Spectral density background "noise" can be divided into two broad classes: (1) uncorrelated white noise which has constant spectral density, and (2) extraneous signals which appear as discrete spectral lines or as a well defined spectrum. These are usually due to either signal processing distortions or stray pickup.

The first noise class is, in general, a colored noise but, when aliased into the Nyquist co-interval, appears for all practical purposes as white (constant spectral density). Usually it is a composite of: (1) receiver noise, (2) analog to digital quantization noise, and (3) Doppler phase noise. Contributions from the various mechanisms depend on received signal power, ADC operating range and radar signal spectral purity as outlined in Sirmans (1974c). However, background noise level observed in the frequency domain depends not only on composite signal-to-noise ratio but also on the weighting function used. With the rectangular weighting, leakage dominates the background level at SNR > 20 dB.

Quantization noise power for the ideal ADC (fig. 3) is small (over 35 dB below signal) if the rms of the digital signal $\sigma_A$ is kept above 30. The usual operating range for $\sigma_A$ is 100 to 600 at Norman and 50 to 200 at Cimarron.

The ratio of spectrum mode to average noise density (excluding the window effects) is shown in Figure 4 for an assumed Gaussian spectrum. Considering

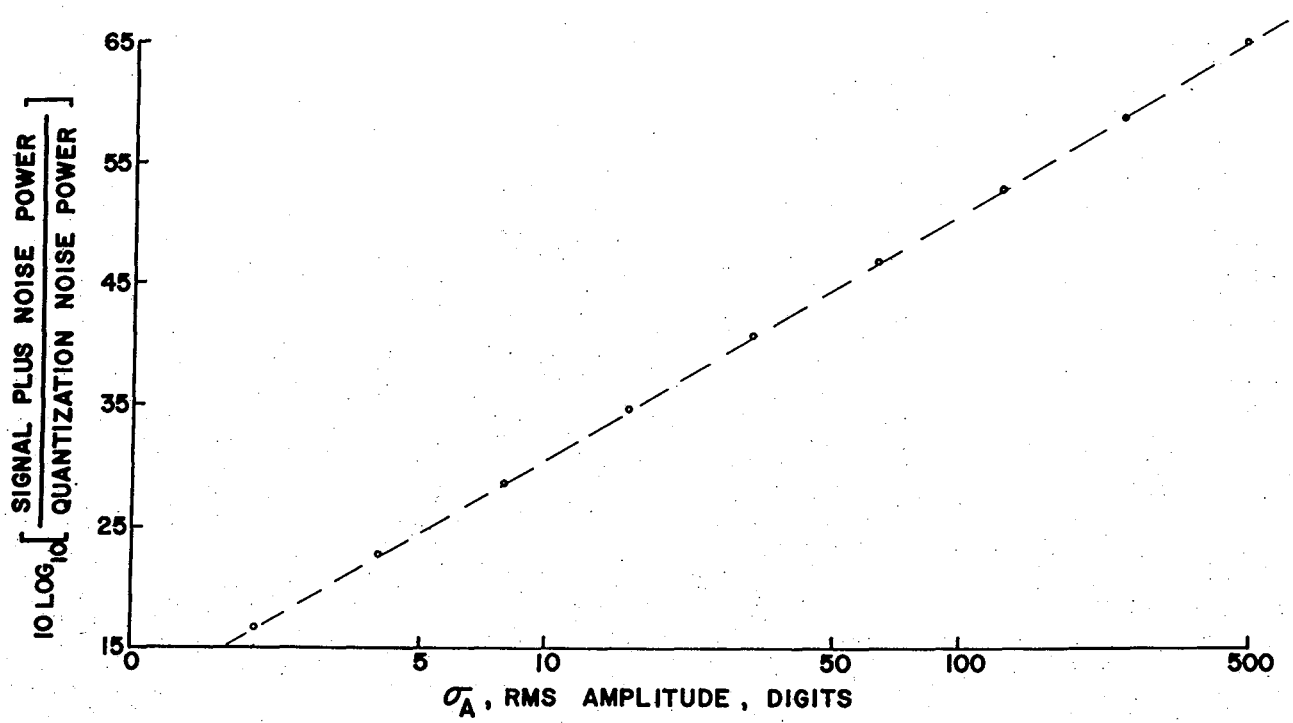



Figure 3. Signal plus noise to quantization noise ratio versus digital RMS amplitude, $\sigma_A$.

the relative magnitude of noise components, it is noted that the spectrum background noise level is dominated by receiver noise up to SNR $\simeq$40 db and by quantization and phase noise above this level. This implies a spectrum mode to average noise density ration-SNR dependency: A ratio of about 10 dB (depending on spectrum width) at a SNR of 0 dB, ratio increasing almost linearly with increasing SNR to a value of about 45 dB and inflecting with asymotope of about 55 dB.

However, this expected behavior is modified considerably at the larger SNR by the window function, especially that associated with the rectangular weight used routinely. As shown in figure 5, the window (sinx/x) has a first sidelobe level of 13.2 dB and skirt sidelobe level of about 39 dB with 64 time samples. Behavior of the observed background level is shown in figures 6, 7, and 8.

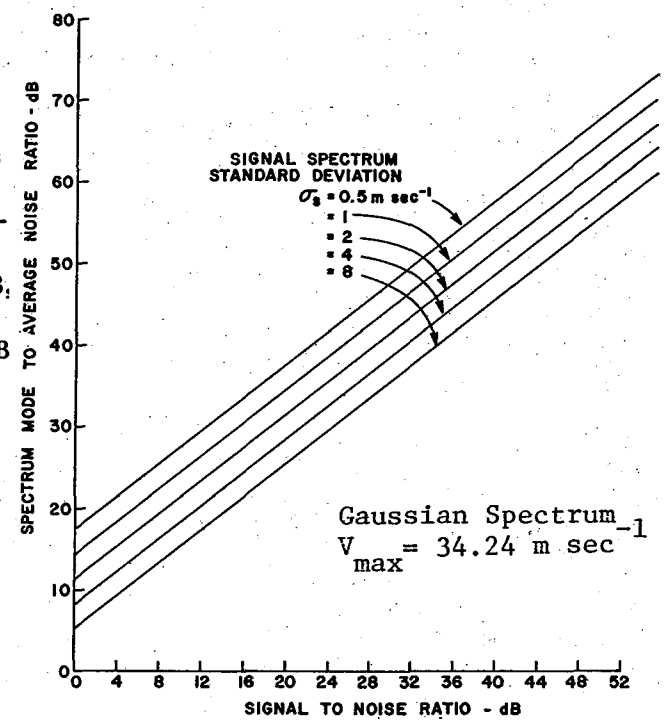



Figure 4. Spectrum mode to average noise ratio as related to signal-to-noise power ratio and spectrum standard deviation.

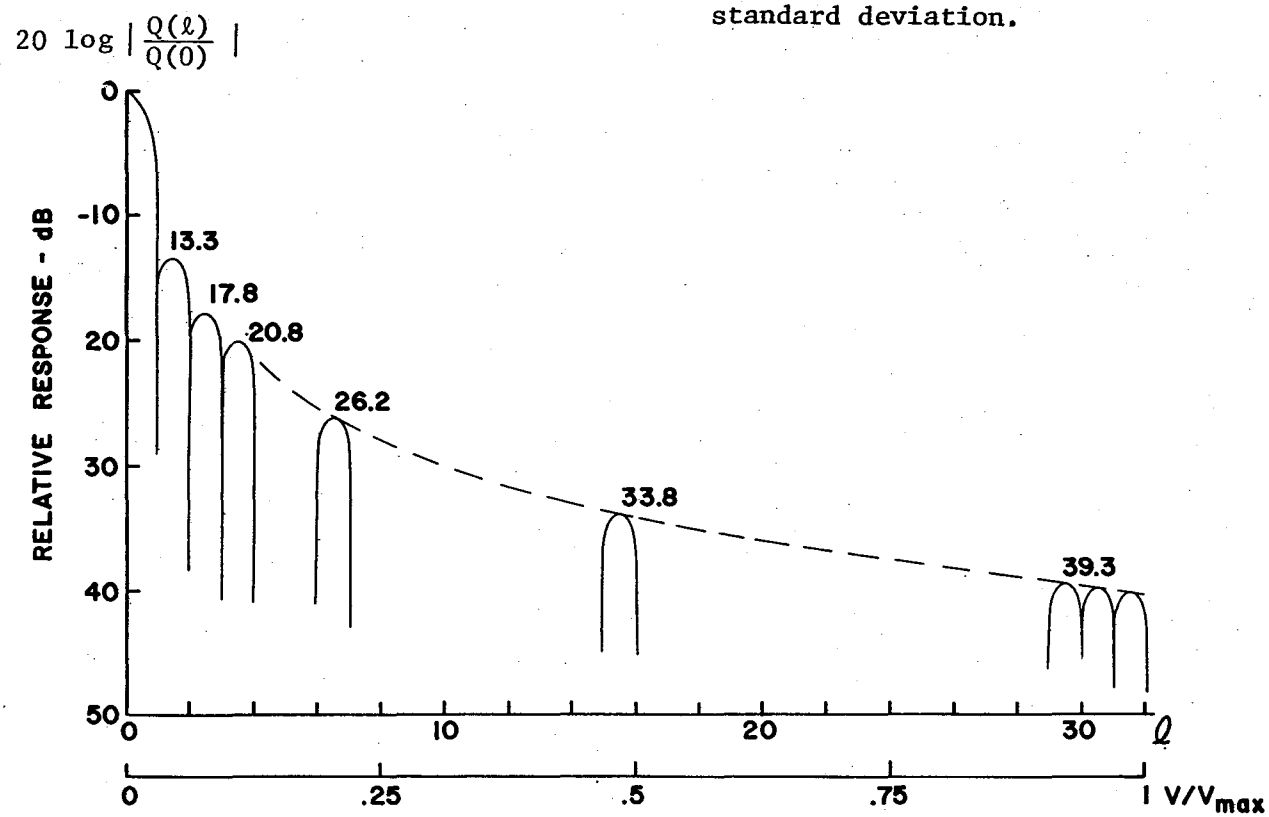
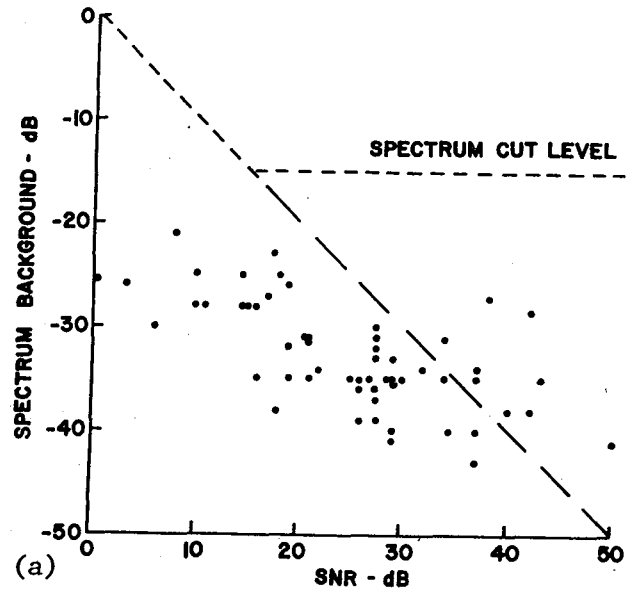



Figure 5. Rectangular weighting function and its discrete Fourier transform: $q(n) = 1$ $\quad n = 1, 2, \ldots N$; $Q(\ell) \approx \sin \pi\ell/\pi\ell$ $\quad \ell = 0, \pm 1, \pm 2, \ldots N/2 - 1$



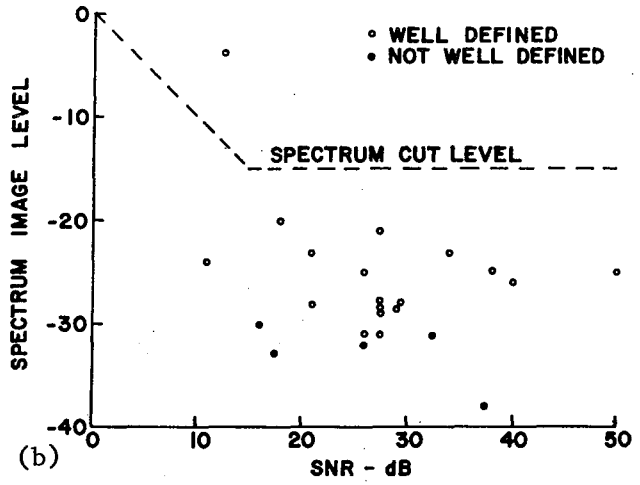




Figure 6. (Above) (a) Spectrum background level. Tape DP 7521, May 19, 1975. (Above, right) (b) Spectrum image level. Tape DP 7521, May 29, 1975. Spectrum cut level of 15 dB below peak is used routinely in the Fourier analysis.

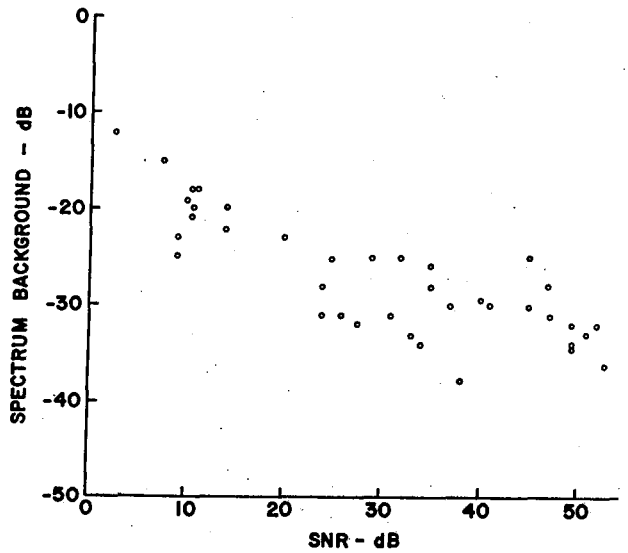
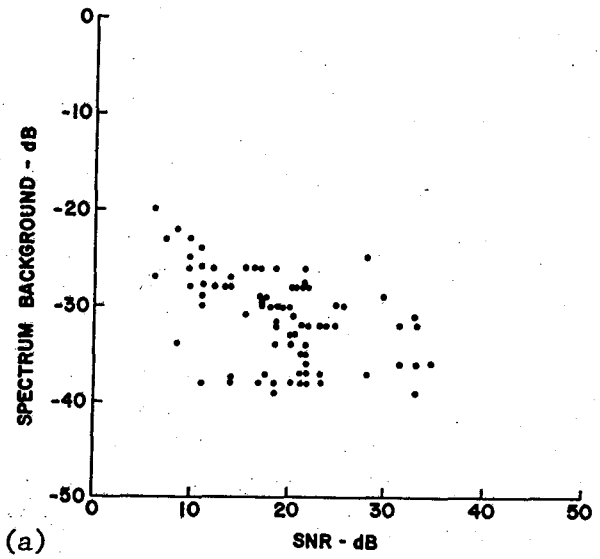
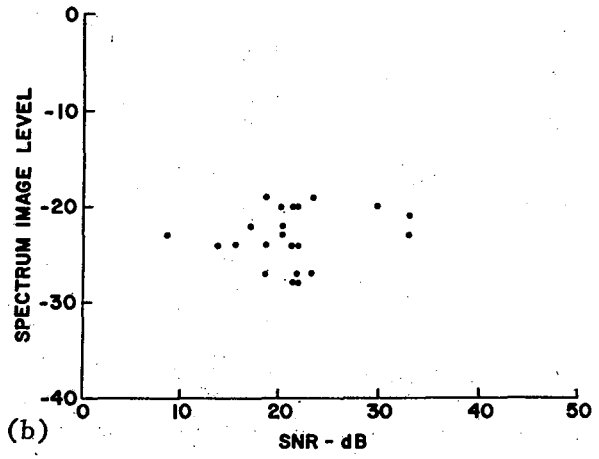



Figure 7. (Right) Spectrum background level. Tape CP 7553, June 13, 1975.

Figure 8. (Below) (a) Spectrum background level. Tape DP 7567, June 13, 1975. (Below, right) (b) Spectrum image level. Tape DP 7565, June 13, 1975.



These scattergrams were plotted from spectrum plots (spot checks of the 1975 data) with average noise level estimated by eye. Note in particular that the background level is limited even at large SNR (>30 dB) to a level commensurate with the skirts of the window function.

It is interesting to compare the background level measured with rectangular weighting to that measured using a weighting function whose transform has lower sidelobes such as the Hanning function (Brigham, 1974) given in Figure 9. This window has a first sidelobe level of 31.4 dB, skirt level well below the expected noise background level with 64 samples but a main lobe width about 1.6 times that of the rectangular window (Nathanson, 1969). The background noise level scattergram (fig. 10) and spectrum width estimate scattergram (fig. 11) illustrate the influence of the two windows.

The CIM complex video contains another type of noise due to spurious convert command to the ADC's. This noise appears as an abrupt discontinuity of the complex video and thus has a uniform spectral density. Certain conditions (depending on the SNR, number and magnitude of the glitches)

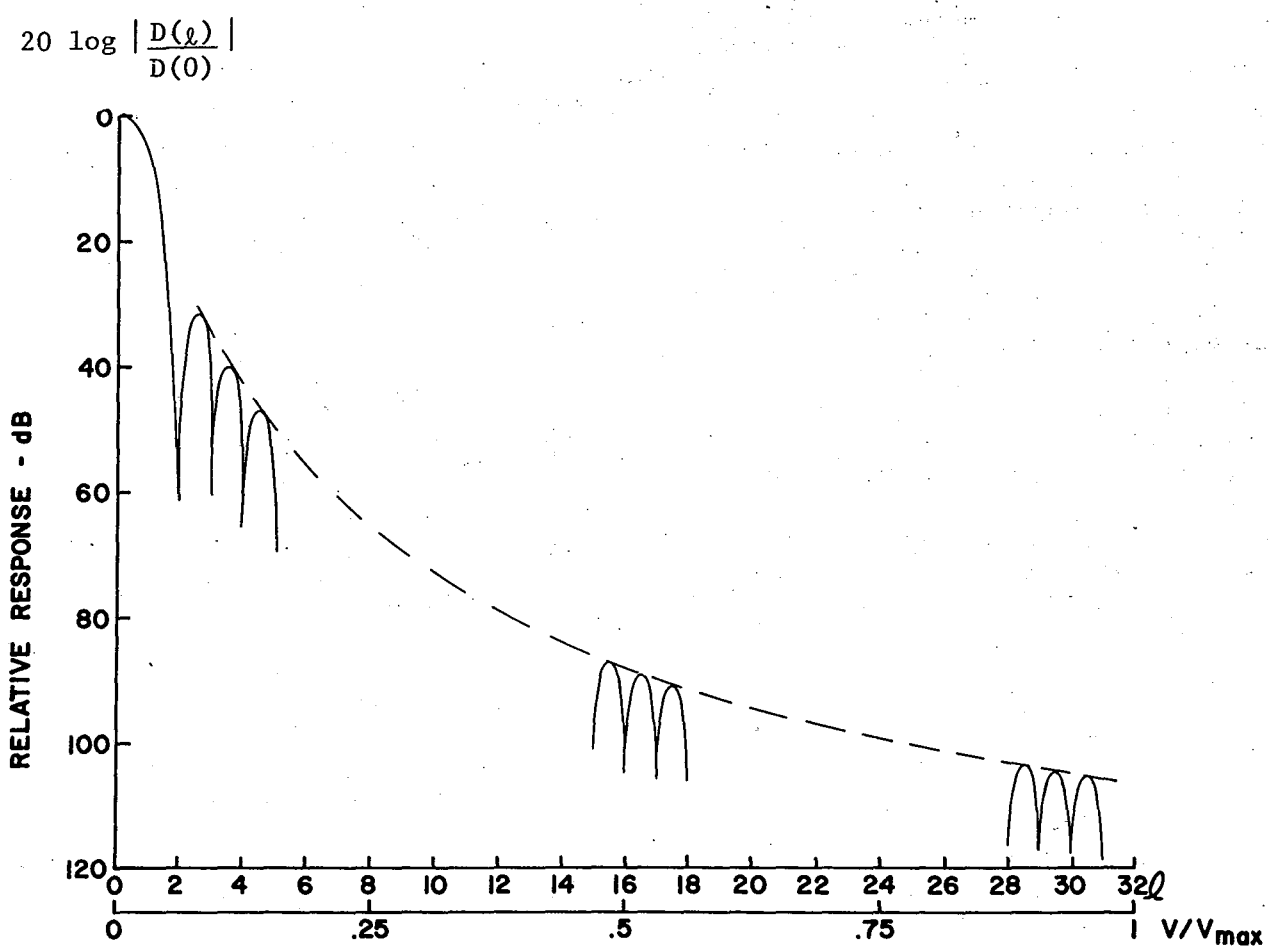



Figure 9. Hanning weighting function: $w(n) = .5(1-\cos\frac{2\pi n}{N})$ $n = 1, 2, 3 \ldots N$

$D(\ell) = 1/4\ Q(\ell - 1) + 1/2\ Q(\ell) + 1/4\ Q(\ell + 1)$ $\ell = 0, +1, \pm 2, \ldots \frac{N}{2} - 1$

$Q(\ell) \approx \frac{\sin \pi\ell}{\pi\ell}$ .

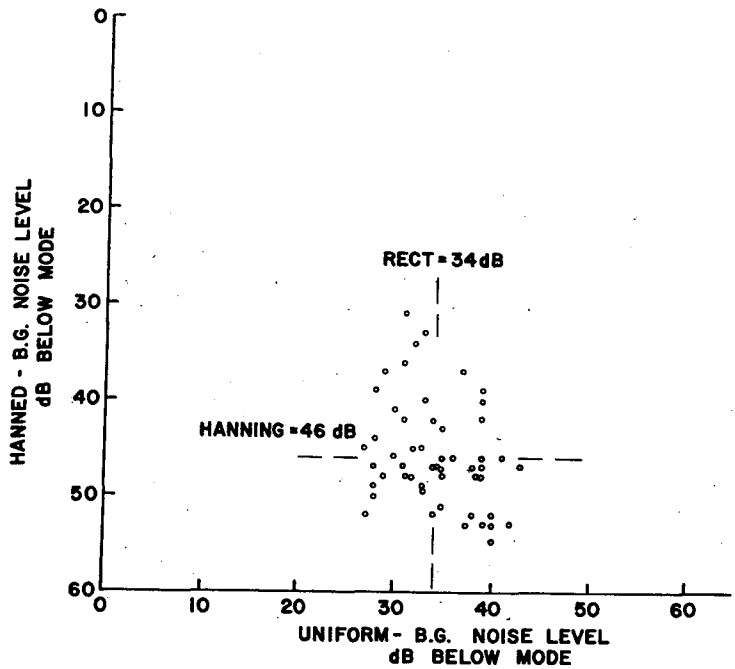
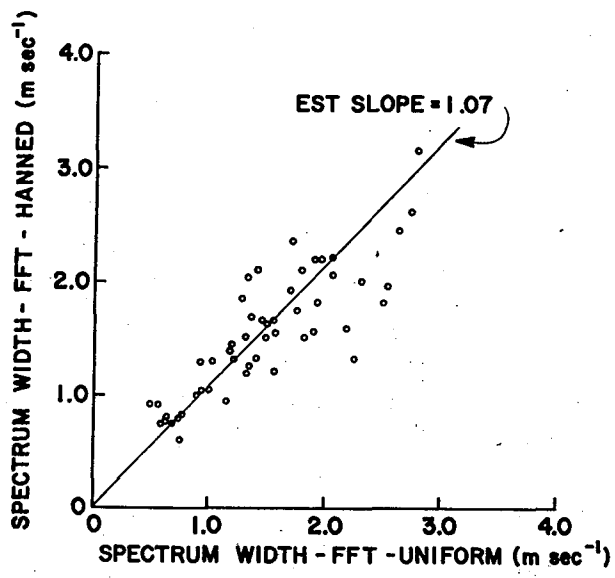



Figure 10. (Left) Background noise level with Hanning wind versus the level with a rectangular window, May 2, 1975. 16 dB < SNR < 57 dB.

Figure 11. (Below) FFT spectrum width estimate, Hanning versus rectangular window, May 2, 1975. 16 dB < SNR < 57 dB.

increase the spectrum background noise level above the spectrum cut threshold and result in a bias of the FFT mean and width estimate, particularly the width estimate. The covariance mean velocity estimate is not biased, although the standard deviation is increased in about 15 percent of the data and appears as an abnormally large width estimate (> 10 m $s^{-1}$). No effort is made to correct these in post analysis, therefore, quantitative estimates of spectrum width from the CIM radar should be made after subjective correction.




Spurious signals due to stray pickup are usually easy to recognize since stray signal frequencies are often multiples of the power service frequency (60 Hz, 120 Hz) and are not in phase quadrature (i.e., appear at both positive and negative frequencies). Although these can be suppressed after the fact, they should be eliminated in signal handling. Little evidence of such signals was noted in the 1975 data. Spurious waveforms due to signal processing appear as harmonics of the input--for instance, the negative first harmonic (image) due to the imbalance of the two video components and odd harmonics with alternating sign generated by clipping of the complex video (Sirmans, 1974c). The third harmonic in particular becomes appreciable (within 30 dB of signal mode) when the ADC maximum span to signal rms ratio is less than about 3. Anomalies of this type were noted in the 1975 data where complex video clipping occurred but present a problem only in studies involving spectrum functional form.

## SECTION 5a

### Range Calibration of Cimarron-Norman Digital Integrator Data Records

Apparent ranges of DI gate locations are derived from observations of known range to fixed point targets (television towers), relative to the radar transmitter pulse, as they appear in the DI data record. True measured target range is obtained by correction of apparent range for transmitter pulse displacement from DI range sampling time, receiver bandwidth, waveguide propagation time and atmospheric refractive index effects. Corrected measured range is then compared with calculated topographic range to verify that all sources of ranging error have been considered.

Cimarron Radar

(1) Apparent range: Figure 12 shows that the transmitted pulse appears in DI gate location number four. The apparent range of gate N, defined as $R_o$, is therefore:

$$R_o = (N - 4)\ (\tau)\ \frac{c}{2}\ m \tag{27}$$

where

N = DI gate of interest

$\tau$ = DI range sampling interval = 1 μs

c = energy propagation speed corrected for atmospheric refractive index. (See Section 2.)

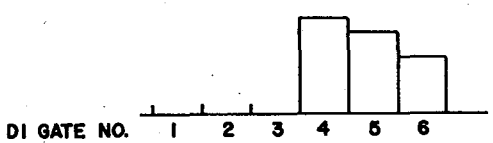
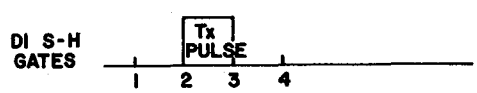
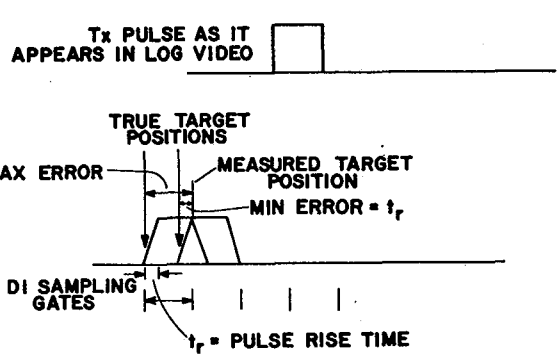



Figure 12. Digital integrator data record.




Sample and hold gates S-H with transmitted pulse $T_x$.




Effects of sampling gates and receiver band width (rise time) on the range correction $R_2$.

(2) Correction terms:

a. Transmitter pulse displacement. The transmitter pulse leading edge precedes the DI gate in which it appears by 300 nanoseconds (fig. 12). A correction term $R_1$ must be added to the apparent range $R_0$.

$$R_1 = 0.3\ (10^{-6})\ (\tfrac{c}{2})\ \text{m} \tag{28}$$

b. Receiver bandwidth. The arrival of the return pulse at the DI is delayed by approximately .31 μs, the reciprocal of the receiver 3 dB bandwidth (3.2 MHz). Note also the effect of the DI range sampling interval on apparent target position (fig. 12). As a general correction factor, $R_2$, these two effects are combined:

$$\left(\frac{1}{BW_{3dB}}\right)\left(\frac{c}{2}\right) \leq R_2 \leq \left(\frac{\tau c}{2}\right) \tag{29}$$

with a mean value of $R_2 = -.65\ .10^{-6}\ c/2$

c. Waveguide propagation delay. Topographic ranges are calculated from known locations of target and radar antenna. Two way propagation times of energy from antenna to radar must be accounted for in range measurements in order to compare them with computed topographic ranges. Energy propagation speed in the waveguide is reduced by a factor of 1.6 from that in free space. Measured propagation delay correction factor is defined as $R_3$.

$$R_3 = 1.6\ D_{WG} \tag{30}$$

where

$D_{WG}$ = physical length of waveguide run.

d. Refractive index effects. The constant c used in all the above range calculations is the energy propagation speed in vacuum divided by a factor of 1.0003.

$$c = \frac{2.998\ (10^8)}{1.0003}\ \text{m s}^{-1} \tag{31}$$

(3) Range calibration equation for point target measurements:

$$R = R_o + R_1 + R_2 + R_3 \tag{32}$$

$$R = [N - 4.347]\ 1.4985\ (10^2)\ \text{m} \pm 52.89\ \text{m} - 49.6\ \text{m}$$

(4) Measured range of fixed targets. Figure 13 shows the true and measured positions of three television towers from the CIM radar.

a. KWTV Tower

$N = 204$

$R = 29.8686\ (10^3)\ m \pm 52.89\ m$

b. KOCO Tower

$N = 211$

$R = 30.9176\ (10^3)\ m \pm 52.89\ m$

c. WKY-TV Tower

$N = 213$

$R = 31.2166\ (10^3)\ m \pm 52.89\ m$

Norman Radar

(1) Apparent range: The transmitter pulse appears in gate number two. $R_o$ is now defined

$$R_o = (N - 2)\ \tau(\frac{c}{2}) \tag{33}$$

(2) Correction terms:

a. Transmitter pulse displacement. For the NRO radar the transmitter pulse precedes the DI sampling gate by 700 nanoseconds. Therefore,

$$R_1 = 0.7\ (10^{-6})\ \frac{c}{2} \tag{34}$$

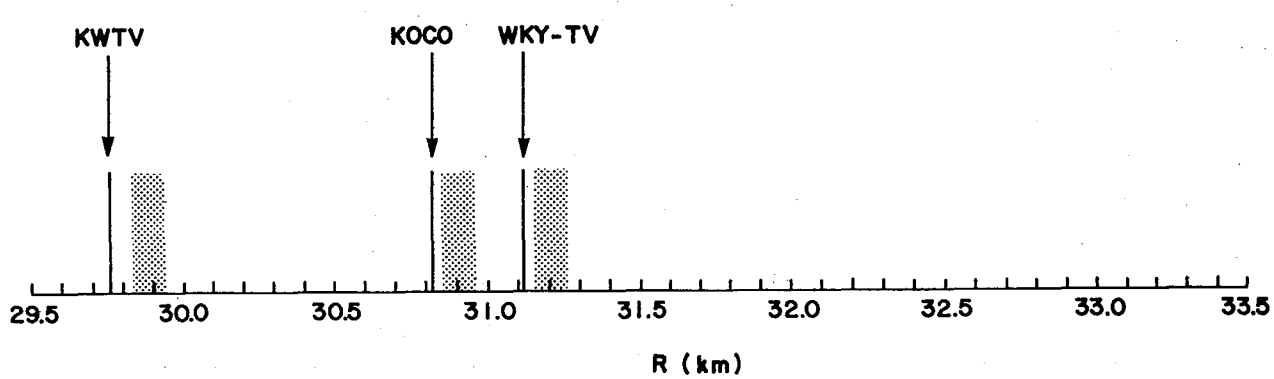



Figure 13. CIM radar derived ranges (shaded areas) within the uncertainty error given by Eq. (29) and true tower ranges (lines).

b. Receiver bandwidth. Measured receiver 3 dB bandwidth is 2.0 MHz. Range sampling interval is 1.0 μs. Correction factor $R_2$ is defined in the same way as for the CIM radars using the above parameters.

c. Waveguide propagation delay. Measured waveguide length is 15.24 meters, however, the transmitter timing measurement is made at the end of a 16.46 m cable which is a one-way waveguide delay (section 5b). Thus, the correction is given by

$$R_3 = 12.2 \text{ m} \tag{35}$$

(3) Range equation.

$$R = R_o + R_2 + R_3 \tag{36}$$

$$R = [N - 1.3]\ 1.49\ (10^2)\ \text{m} - 136.4\ \text{m} \pm 37.46\ \text{m}$$

(4) Measured range of fixed targets. Figure 14 shows the true and measured positions of three television towers from the NRO radar.

a. KWTV Tower

$N = 235$

$R = 34.895\ (10^3)\ \text{m} \pm 37.46\ \text{m}$

b. KOCO Tower

$N = 244$

$R = 36.244\ (10^3)\ \text{m} \pm 37.46\ \text{m}$

c. WKY-TV Tower

$N = 249$

$R = 36.993\ (10^3)\ \text{m} \pm 37.46\ \text{m}$

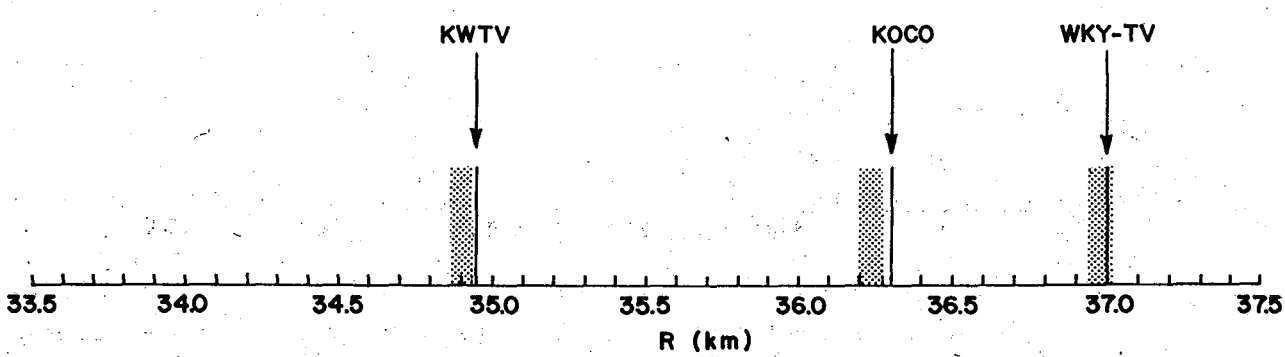



Figure 14. Norman radar derived (shaded) and true (lines) tower ranges.

## Section 5b

### Range Timing Check for Norman Doppler

The following description of a ranging check (using "known" range of WKY tower) illustrates the technique used in determining slant range with NSSL radars, and offers an error analysis of measured radar parameters.

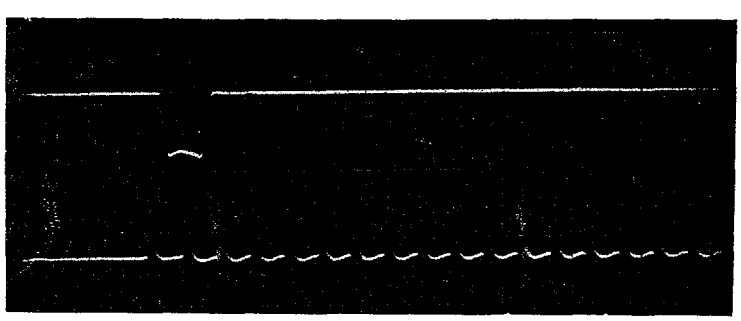
A sketch of the radar integrator timing is shown in Figure 15. Important parameters are the time ($T_D$) between the leading edge of the transmitter pulse (time zero) and first integrator sample hold location ($L_1$), and the spacing between samples (S). In making this measurement the $T_x$ pulse is viewed at the end of a 16.46 m coax (RG-8) and 15 dB coax attenuator connected to forward power jack of the directional coupler. Delay due to this cable is approximately 0.09 μs or about the same as delay from directional coupler to antenna aperture (one-way waveguide run). In the ranging calculation a correction ($T_A$) of 0.1 μs is made for the delay from aperture to directional coupler.

The intensity sample-hold command is approximately 40 ηs wide with leading edge occurring 50 ηs prior to data sample (uncertainty of ± 300 pico s). The data sample is the input data value exponentially weighted from the trailing edge of the sample window with time constant of about 10 ηs. These uncertainties are small compared to that associated with definition and measurement of the $T_x$ pulse leading edge and are not accounted for in the ranging delay.

Time between sample-hold commands for A channel is the radar system Coho signal period divided by 30, i.e., for a 30 MHz reference the spacing is 1 μs, for B channel the division is 30 x 2/3 and the spacing is 1.5 μs. For the NRO Doppler this signal was 30.0079 MHz (for the WKY test, May 15, 1975) with associated spacing of 0.9997367 μs. Time delay, DLY, corresponding to a given integration location (1 designates the first location) is given by:

$$\text{DLY} = [(\text{Location} - 1)(\text{spacing}) - 0.3]\mu\text{s} \ . \qquad (37)$$

The observed delay to a target at a given range is the sum of delay due to range (from the antenna) and any fixed delays in the receiver chain. In the case of NRO Doppler the receiver chain delay is composed of two parts: the delay from the aperture to directional coupler, $T_A$, and the delay from directional coupler to sample hold input or receiver initial delay, $T_I$. This



Transmitter pulse

Integrator sample hold commands

Figure 15. Time base = 2 μs/cm

second parameter is loosely related to number of stages and values of the lumped constants in the receiver chain and has a measured value of 0.1 μs for both the linear and log receivers.

The return signal is subject to a further delay due to finite receiver response. This "rise time" ($T_R$) is an inverse function of receiver 6 dB bandwidth ($BW_{6dB}$) and is given to a good approximation (Skolnik, 1969) by

$$T_R = \frac{1}{BW_{6dB}} = \frac{1}{2.88\ \text{MHz}} = .35\ \mu s\ . \tag{38}$$

Thus, the target delay (from time zero) is

$$DLY = \frac{\text{Range}}{c/2} + T_R + T_A + T_I \tag{39}$$

where c is the propagation constant.Eq. (31).

The range from the NRO Doppler to WKY tower based on longitude-latitude is calculated to be 36.986 km with estimated uncertainty of 30 m. Delay to WKY tower is given by

$$DKY_{WKY} = [\frac{36986}{299.686/2} + .55]\mu s = (246.83 + .55)\mu s - 247.38\ \mu s\ . \tag{40}$$

Substituting this $DLY_{WKY}$ into Eq. (37) and solving for location, we have

$$\text{LOCATION} = \frac{(247.38 + 3)}{.9997367} = 248.74 \tag{41}$$

Since the above delay is measured from the leading edge of the 1 μs $T_x$ pulse (time zero) this is the position of the target full response which should appear on the digital listing (fig. 16a) at location 249 (which it does).

The basic range resolution of 150 m that sampling imposes can be reduced for point target measurement by noting target relative response on the integrator output (i.e., the digital listing, fig. 16a) or examination of the log video relative to sample hold commands (fig. 16b). The latter must be done carefully, however, since the log receiver response to leading and trailing edges of a point target is not symmetrical and there is a stretching of the full response width.

Tabulation of uncertainties associated with the timing parameters is given in Table 13.

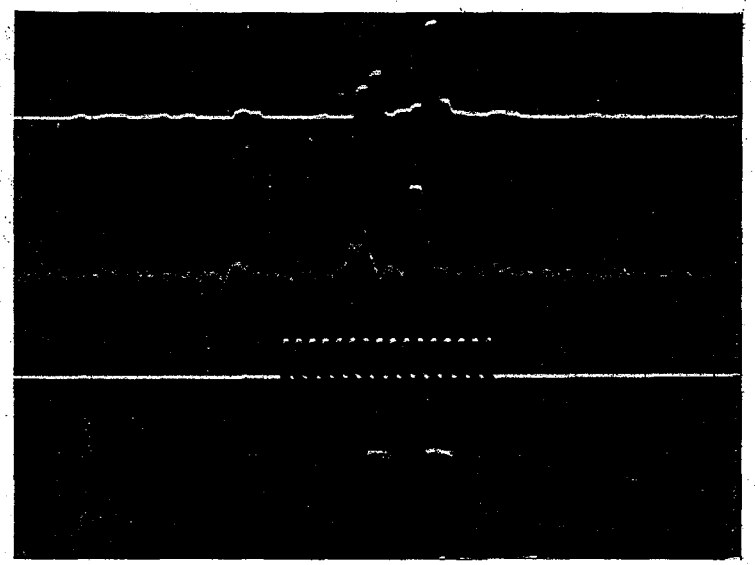
In practice the problem is not to verify location of a known target but to assign a representative range to the sample taken at a precribed time, i.e., what is the range associated with a given intergrator location? This is found by first combining receiver initial delay and rise time to form the receiver nominal delay, $T_N$ (Ruston and Bordogna, 1966), i.e., delay from excitation (transmitter pulse leading edge) to 50 percent response ($T_I + T_R/2$),

WKY

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 8 | 8 | 8 | 18 | 31 | 11 | 7 | 14 | 48 | 15 | 11 | 10 | 7 | 8 | 9 | 8 |

240 245 Location 250 255

(a)



Integrator Analog Output

Log Video (strongest signal is from WKY tower)

Doppler Gates
Delay to the first gate = 242 μs
Doppler gate spacing = 1 μs

Time Base = 5 μs/cm

(b)

Figure 16. (a) Integrator listing of range-intensity for point targets (WKY tower complex). AZ = 256.2°, $E_L$ = 1.0°, May 15, 1975. (b) "A" scope display of WKY tower complex.

which gives an integrator location range equation:

$$R_L = [(L - 1)S - T_D - T_A - T_N]\frac{c}{2} \tag{42}$$

where

$R_L$ = range of location L (m)

L = integrator location

S = integrator spacing (s)

$T_D$ = delay from leading edge of $T_x$ pulse (s) to first sample hold location

$T_A$ = delay from aperture to directional coupler (s)

TABLE 13

Timing Parameters

| Parameter | Value | Estimated Uncertainty |
|---|---|---|
| Initial delay, $T_D$ | -0.3 μs | 0.1 μs |
| Spacing, S | 0.99974 μs | 0.0001 μs* |
| Rx initial delay, $T_I$ | 0.1 μs | .05 μs |
| Rx rise time, $T_R$ | 0.35 μs | .05 μs |
| Delay from $T_x$ measurement port to antenna aperture, $T_A$ (waveguide delay) | 0.1 μs | - |

In addition, the measurement is subject to variations in propagation time of the order of $10^{-4}$ (0.01 percent).

*This is based on a measured standard deviation of 410 Hz for seven measurements of the reference signal from May 15 to June 20, 1975. The mean value was 30.007743 MHz.

$T_N$ = receiver nominal delay correction = $T_I + T_R/2$

$T_I$ = receiver initial delay (s)

$T_R$ = receiver rise time (s)

The reference (T=0, R=0) in this measurement (Eq. 43) is the transmitter leading edge. Thus, the measurement represents a volume in space having maximum range of $R_L$ and minimum range of $R_L - c\tau/2$ where $\tau$ is the transmitter pulse width (fig. 17).

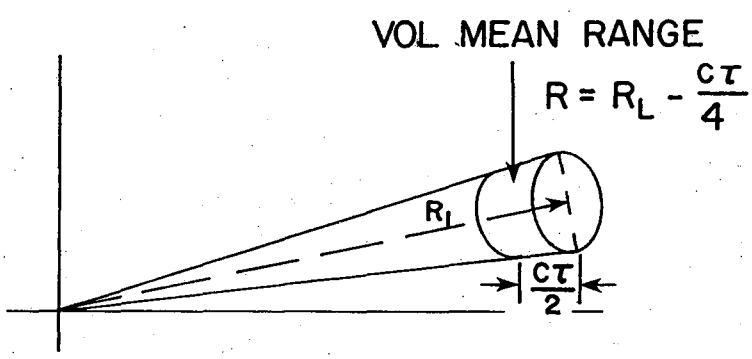



Figure 17. Radar sample volume.

The range to the center of the volume

$$R = R_L - \frac{c\tau}{4} \tag{43}$$

is probably the most convenient range parameter for routine use. In terms of this range and for mean spacing of .99974 μs, the range equation for the NRO Doppler digital integrator is given by

$$R = [(L - 1)S - T_D - T_A - T_N - \frac{\tau}{2}] \frac{c}{2} \tag{44}$$

$$R = [(L - 1)(.99974) - 1.175] \frac{c}{2} (10^{-6}) \text{ m} \quad . \tag{45}$$

The uncertainty of this range is, of course, the combined uncertainty of the various parameters as given in Table 13. The most significant of these is the measurement of $T_D$ (~0.1 μs) and the specification of receiver nominal delay time (~.05 μs). Treating all uncertainties as uncorrelated random variabiles, the estimated standard deviation of the range measurement is 20 m.

## SECTION 6

## Sun Flux Measurement Comparison

### CIM-NRO Dual Sunshot, June 2, 1975

Solar radiation in the S-band portion of the electromagnetic spectrum offers a convenient source for comparing measurements by NSSL's radar with an independent measurement made by the Alconquin Radio Observatory in Ottawa, Canada. Solar flux measurements with accuracy of 0.1 dB are made at the Observatory and reported on NBS radio station WWV hourly. The comparison will help establish the accuracy to which received power is measured at each radar site.

### Received Power Calculation

Predicted values of power received at the radar are computed from sun flux and radar system parameters.

$$P_r(\text{dBm}) = 10 \log [F\, A_{eff} BW_N] - L_{WG} - L_R + 30 \qquad (46)$$

where

$P_r(\text{dBm})$ = predicted power incident at receiver input port in dBm units

$F$ = Observatory measured solar flux watts ($m^{-2}$ $Hz^{-1}$)

$A_{eff}$ = effective antenna aperture ($m^2$) calculated from measured antenna gain G

$A_{eff} = G\lambda^2/4\pi$

$\lambda$ = radar wavelength (m)

$BW_N$ = receiver noise equivalent bandwidth (Hz)

= 1.06 $BW_{3dB}$ (where $BW_{3dB}$ is the half power bandwidth)

$L_{WG}$ = one way waveguide loss (dB)

$L_R$ = one way radome loss (dB)

### Cimarron Radar (CIM)

$F = 67.02\ (10^{-22})\ W m^{-2} Hz^{-1}$ [Datum from Observatory. Measurement made June 2, 1975, 1200 CST.]

$A_{eff} = 38.1\ m^2$

$L_{WG} = 1.8$ dB

$L_R = 1.0$ dB

$BW_N = 3.39\ (10^6)$ Hz

$P_r = 10 \log[6.702(10^{-21})\ 2.91(10^{-1})\ 3.39(10^6)] - 2.8 + 30 = -93.4$ dBm

Measured received power, $P_{rm}$, is derived from the data tape digital integrator record and the radar calibration curve.

$$P_{rm} = P_S - L_c + A_{LOG} + B_t \tag{47}$$

where

$P_{rm}$ = observed power at receiver input port with antenna pointing at sun

$P_S$ = observed sun power derived from receiver calibration

$L_c$ = cable loss of the signal generator used in calibration

$A_{LOG}$ = correction required due to log receiver signal averaging, i.e., signal generator and sun signals having different amplitude statistics

$B_t$ = digital integrator truncation bias of .6 dB

$P_{rm} = [-90.0 - 6.7 + 2.5 + .6]$ dBm $= -93.6$ dBm

Differences in measured and calculated received powers ($P_r - P_{rm} = -.2$ dB) reflect uncertainties in measured radar parameters. This value indicates an error of -0.2 dB with CIM inferring a solar flux .2 dB less than reported by the Observatory.

Norman Radar (NRO)

Following the same procedure as for the CIM radar, yields calculated power of -94.2 dBm obtained using the NRO parameters:

$A_{eff} = 42.1\ m^2$

$L_{WG} = 1.0$ dB

$BW_N = 2.12\ (10^6)$ Hz

$L_R = 1.0$ dB

$P_r = -94.2$ dBm

$P_{rm} = [-88.7 - 9.5 + 2.5 + .6]$ dBm $= -95.1$ dBm

Difference between calculated and measured powers is -.9 dB and the difference between the two radars is about 0.7 dB with NRO inferring a solar flux less than CIM.

CIM-NRO Dual Sunshot, June 16, 1975

Another set of measurements were taken on June 16 with the following results:

CIM

$P_r$ = -92.6 dBM

$P_{rm}$ = -93.9 dBm

Difference = -1.3 dB

NRO

$P_r$ = -93.6 dBm

$P_{rm}$ = -94.6 dBm

Difference = -.8 dB.

Conclusion

Powers from the common source measured by the two radar differ by less than 1 dB. This difference is attributed to radar parameter (i.e., antenna gain, losses, etc.) measurement errors and is well within practically achievable tolerances.

## SECTION 7

### Standard Deviation of Estimates

Standard deviations of the estimates of mean velocity, spectrum width and intensity have been previously analyzed and the 1975 data is little different from previous data sets. However, the hardware changes (ADC and AGC at both sites) and tighter quality control provide valid estimates over a wider range of sign levels.

Data suitable for deriving standard deviation of estimates were taken at various times during the season but only that of May 29 has been extensively analyzed. These results, as well as results from some of the 1974 data (Sirmans, 1975) are given in the following scattergrams.

A scattergram of standard deviation of intensity estimate versus estimated spectrum width parameter is shown in Figures 18a and b. The time constant of 64 system periods ($T_s$) shown in Figure 18b (k=3) was used in routine data acquisition during the 1975 season. Note that the standard deviation of the intensity estimate approaches 3 dB for smaller values of spectrum widths encountered (~1 m $s^{-1}$).

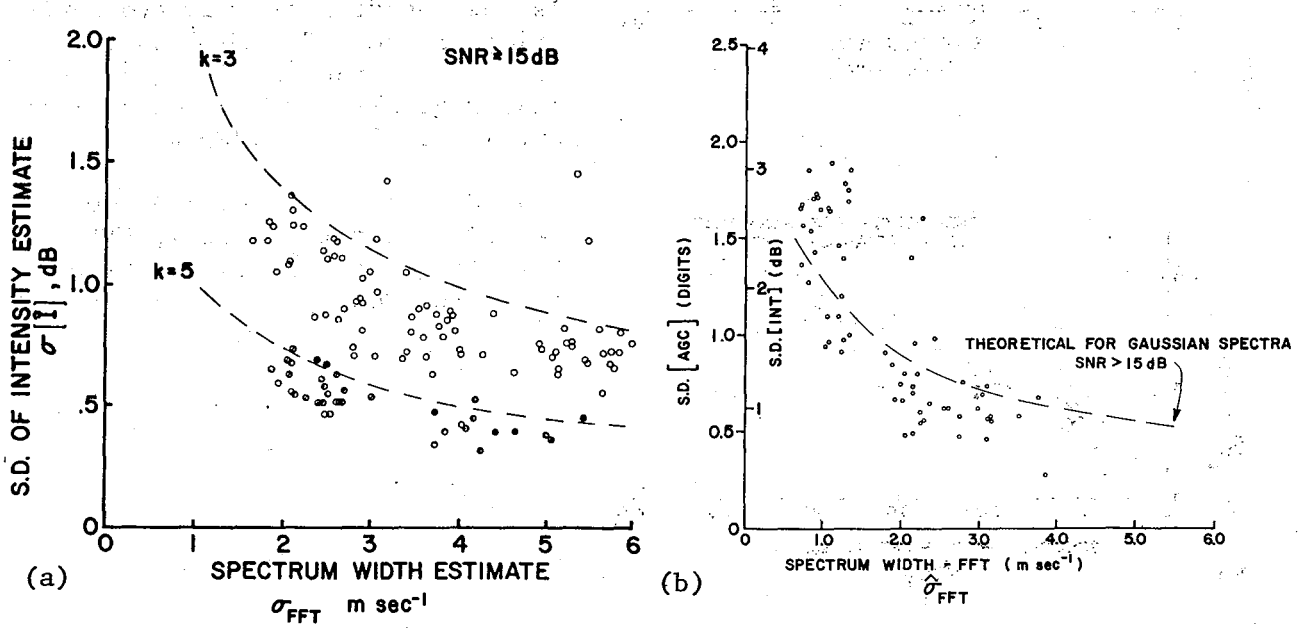
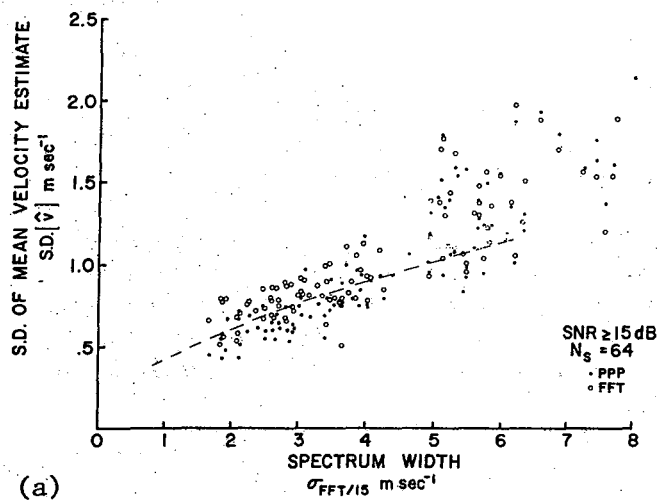


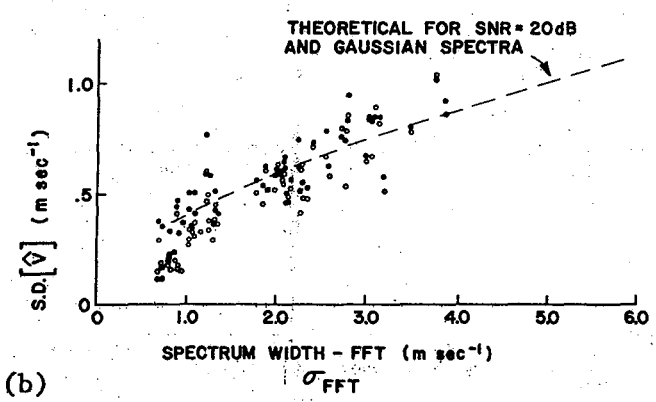

Figure 18. (a) Scattergram of intensity estimate standard deviation versus estimated spectrum width. SNR > 15 dB. Dashed curves are theoretical for Gaussian spectra. k is the time constant parameter in recorded data header, ($T_e = 2^{k+3} T_s$), k = 3 is a time constant of 64 radar periods, k = 5 is a time constant of 256 radar periods. Mean trend has been removed by linear regression. Data taken April 27, 1974 with Norman Doppler. (b) Standard deviation of intensity estimate, k = 3. Mean trend removed. Data taken May 29, 1975.

A scattergram of standard deviation of mean velocity estimate is given in Figures 19a and b, and scattergrams of the standard deviation of width estimates is given in Figures 20a, b, and c.

All of the observed statistics agree reasonably well with theoretical predictions (Sirmans and Bumgarner, 1974, and Sirmans and Doviak, 1973).




(a)

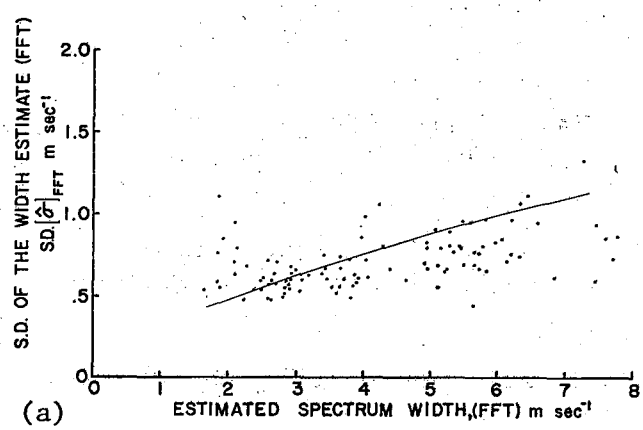



(b)

Figure 19.

(a) Scattergram of FFT and PPP mean velocity estimate standard deviation. Spectrum width estimate by the FFT with a 15 dB (below spectrum mode) threshold (FFT/15). This estimate has been adjusted for the expected bias of Gaussian spectra. Time dependent mean velocity trend was removed by least squares linear regression. Dashed curve is the theoretical standard deviation of the FFT with Gaussian spectra and SNR of 20 dB (Berger and Groginsky, 1973). Data taken April 27, 1974 with Norman Doppler.

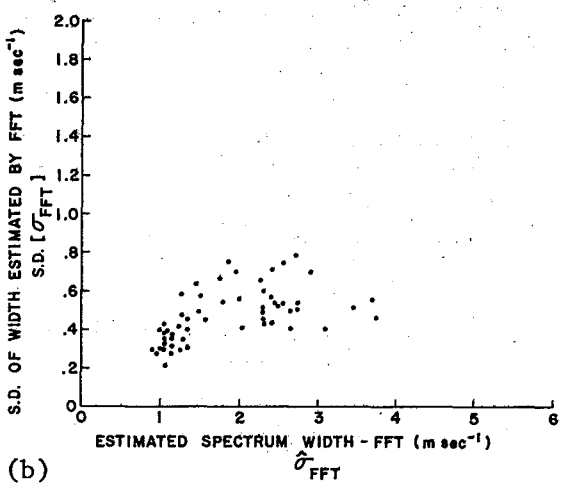
(b) Standard deviation of mean velocity, estimate FFT=•, PPP=o. Data taken May 29, 1975. Mean trend removed by linear regression.




(a)

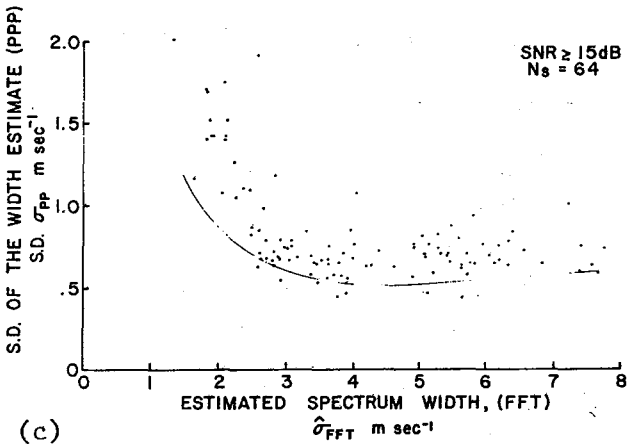
Figure 20.

(a) Scattergram of FFT width estimate standard deviation versus FFT width estimate. No adjustments for estimate bias have been made. Data set has 15 dB < SNR < 30 dB. Estimates made with 64 time samples. Trend removed by linear regression. Data taken April 27, 1974, with Norman Doppler. Solid curve is theoretical for Gaussian spectra and SNR = 15 dB (Berger and Groginsky, 1973).




(b)

(b) Standard deviation of spectrum width estimate by FFT. Data taken May 29, 1975. SNR > 15 dB; $N_s$ = 64. No adjustment for estimate bias. Mean trend was not removed.




(c)

(c) Scattergram of PPP width estimate standard deviation versus width estimate by FFT/15. No adjustments for estimate bias have been made. Data set has 15 dB < SNR < 30 dB. Estimate made with 64 time samples. Data taken April 27, 1974, with Norman Doppler. Solid curve is theoretical for Gaussian spectra and SNR = 15 dB (Berger and Groginsky, 1973).

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