TEXAS HIPLEX
INTERIM PROGRESS REPORT
LP-11

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Interim Progress Report for April 1-September 30, 1977

Prepared for:

DIVISION OF ATMOSPHERIC WATER RESOURCES MANAGEMENT
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TEXAS DEPARTMENT OF WATER RESOURCES
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October 10, 1977

Dr. Archie M. Kahan, Chief
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Dear Dr. Kahan:

In compliance with Amendatory Agreement No. 1 to Contract No. 14-06-D-7587 between the Bureau and the Department, we are herewith submitting twenty (20) copies of the interim progress report on the Texas High Plains Cooperative Program (HIPLEX). The report discloses work performed, all data and information obtained, and all results achieved during the period April 1 - September 30, 1977, and is composed of four sections:

(1) A description of activity in each of the program areas addressed in the Texas HIPLEX 1977-78 Operations Plan;
(2) A brief statement of work planned for the next, 6-month reporting period (October 1, 1977 - March 31, 1978);
(3) A list of personnel involved in the 1977 Texas HIPLEX Program; and,
(4) Three appendices containing information on studies conducted by the Department staff in support of the Texas HIPLEX Program.

If you have any questions concerning the interim progress report or if you need additional details, please do not hesitate to contact us.

Sincerely,

Herbert W. Grubb

Herbert W. Grubb
Director, Planning & Development

P.O. Box 13087 Capitol Station • Austin, Texas 78711 • Area Code 512/475-3187

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SECTION I

WORK PERFORMED DURING THE PERIOD

APRIL 1 - SEPTEMBER 30, 1977

TEXAS DEPARTMENT OF WATER RESOURCES

"MANAGEMENT OF THE TEXAS HIPLEX PROGRAM AND SUPPORT STUDIES"

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During the 6-month period, April 1 - September 30, 1977, the Department staff negotiated and awarded eight contracts for work and services in support of the Texas-HIPLEX Program (Table 1). In addition, the contract (No. 14-70033) to the Colorado River Municipal Water District for rain-gage, rawinsonde, and other meteorological support services was extended to December 31, 1977 and the contract (No. 14-60029) to Meteorology Research, Inc. for the collection of M-33 radar data at Snyder, Texas and the subsequent processing and analysis of these and other data was extended to September 30, 1977. Furthermore, consultant contracts were awarded to four members of the Texas-HIPLEX Advisory Committee for State Fiscal Year 1978, viz., Dr. James R. Scoggins (Texas A&M University), Dr. T. B. Smith (Meteorology Research, Inc.), Owen H. Ivie (Colorado River Municipal Water District), and Dr. Donald Haragan (Texas Tech University).

During the field portion of the 1977 Texas-HIPLEX Program, the Department provided a staff meteorologist as Field Manager at the Big Spring base of operations. He coordinated the activities of each of the participating groups in the Program for the duration of the field phase--which extended from June 1 to July 15--maintained liaison between the Department staff and Bureau personnel, and determined the operational mode for each day during the 45-day period.

The Department's resident meteorologist at Big Spring

Table 1. Contracts Awarded by the TDWR During the Reporting Period for HIPLEX Support Services

Contract Number	Organization	Period Begin	Period End	Purpose
14-70029	Dept. of Geosciences Texas Tech University	5-05-77	8-31-77	describe Texas HIPLEX Precipitation patterns
14-70030	Dept. of Meteorology Texas A&M University	4-22-77	8-31-77	analyze mesoscale data collected in summer of 1977
14-70031	Big Spring Aircraft, Inc.	5-05-77	7-31-77	provide observation aircraft
14-70034	Dept. of Geosciences Texas Tech University	5-26-77	8-31-77	analyze satellite data in support of the Texas program
14-70032	Dept. of Meteorology Texas A&M University	5-18-77	8-31-77	construct a radar-echo climatology for the Texas HIPLEX Region
14-80002	Dept. of Meteorology Texas A&M University	9-30-77	8-31-78	continue analysis of mesoscale data
14-80003	Dept. of Geosciences Texas Tech University	9-01-77	12-31-77	continue satellite derived cloud clima-tology
14-80004	Dept. of Meteorology Texas A&M University	9-30-77	1-31-78	continue construction of radar-echo climatology

provided forecasting support during the field portion of the Program, as well as support to the cloud-seeding operations of the Colorado River Municipal Water District, which were conducted throughout the 6-month period covered by this report. Local forecasts and next-day outlooks were issued daily to assist each of the Texas-HIPLEX Program participants in planning their respective activities. The on-site forecaster also made hourly surface observations, took sky photographs, and obtained ice nuclei counts on each day during the field program. In addition, he collected local climatological data and obtained and stored synoptic and facsimile data from in-house teletype and facsimile circuitry. Much use was made of the computer data terminals at the Big Spring Meteorological Facility to process forecast and rawinsonde data and transmit these data to the Bureau's computer in Denver.

Work begun in early 1977 on a computer model to allow the prediction of the occurrence of thunderstorm days in the Big Spring area continued during the reporting period. The model was used during the 1977 field phase of the Program. However, because erroneous data had been entered in the computer data bank, products from the prediction model proved to be unsatisfactory. After the termination of the field phase of the Program, corrections to these erroneous data were made, and subsequent refinements of the computer program were introduced.

Board staff members readied for operation a total of

80 gages which constituted the 1977 HIPLEX recording rain-gage network: 69 Belfort recording rain-gages, 9 Fischer-Porter gages, and 2 Meteorology Research, Inc. Tipping Bucket gages. With the cooperation of Colorado River Municipal Water District, ice nuclei counting equipment was installed and maintained during the reporting period at four locations: Big Spring's Howard County Airport, Lubbock's Texas Tech University, Stanton, and Colorado City.

The Texas-HIPLEX Advisory Committee met on June 9-10 at Big Spring to review the activities on-going at the Texas-HIPLEX Project site and in Austin on September 7 to formulate plans for 1978. Department staff personnel visited the HIPLEX site during the field program and obtained photographic data of each portion of the field activities.

The Department's Big Spring resident meteorologist performed an evaluation of forecasts issued in support of the 1977 Texas-HIPLEX Field Program. This evaluative report is included as Appendix A of this report. Plans were developed to permit the analysis of ice-nuclear count data obtained during the 1977 cloud-seeding season at Big Spring from the four sites where counting equipment were operated.

The Department staff continued work on Part 3 of the Federal-State cost-sharing study on the agro-economic effects of weather modification activities in the Texas-HIPLEX region. Research focused during the reporting period on the importance of additional rainfall in the irrigation-agricultural sector of the economy as it pertains to declining ground-water pumping requirements in the region.

METEOROLOGY RESEARCH, INC.

"SYNDER RADAR-DATA-COLLECTION PROGRAM

AND DATA ANALYSIS"

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1. Introduction

The objectives of the MRI portion of the Texas Hiplex program have been listed in descending order of priority as:

a. Acquisition and processing of quantitative radar data

b. Development and interpretation of cloud and radar climatologies

c. Processing and interpretation of data related to the mesoscale experiments

Work accomplished during the past six months has included a six weeks field program in conjunction with the 1977 mesoscale experiment, the processing of 1976 radar tapes, and quality control runs on the 1977 data. In addition, analysis of the mesoscale system of June 22-23, 1976 was initiated and several details of the precipitation characteristics in the Big Spring area were determined.

Processing of the radar data has been beset with several significant difficulties. Chief among them have been changes in the Bureau tape format and an unexpected number of errors introduced by the digital processor. In spite of considerable rework at the beginning of the 1977 season the processor again exhibited occasional data errors but on a much reduced scale compared to the 1976 problems. In September, the radar processing system was reorganized and new programs outlined to more effectively transform the field data into the appropriate Bureau format.

2. Field Operations

The 1977 field operations in Snyder were initiated on May 17 for the purposes of putting the radar into operational condition and to rework the digital processor in order to eliminate some of the errors observed in the 1976 tapes. Mr. Mark Gardner, formerly of Illinois State Water Survey, was responsible for the initial design and manufacture of the processor and provided the principal corrective actions during May. The processor problems were gradually solved by late May at which time arcing in the motor-generator set began to introduce a number of errors onto the tape records. This problem was solved early in June and caused no further difficulty during the summer.

Two additional errors, however, developed in the processor during the field operational period. One of these was an occasional 8-bit error which was subsequently found to be correctable during computer processing. The other was a 32-bit, intermittent error which has proved more difficult to handle by processing techniques.

The 1977 dates when radar tapes were generated are shown in Table 1. After July 9 a calibration of the 10 cm radar was accomplished using a free-floating balloon to support a calibration sphere. The calibration showed that the antenna system gain was within one db of the value obtained in 1975. The radar was shut down on July 15 and personnel returned to Altadena.

A light aircraft (Cherokee) from Big Spring Flying Service was again used to measure cloud base heights, updrafts near cloud base and humidity variations in the sub-cloud layer. Data were recorded on cassette tape. These data have been transferred to the Bureau of Reclamation computer file in Denver and can now be converted to engineering units and analyzed. A list of cloud base sampling dates and times is given in Table 2.

3. Data Reduction

3.1 Radar Data

The 1976 radar data were plagued with two principal problems; arcing of the waveguide and errors in the digital processor. Major efforts were made to correct the waveguide problems during the 1976 summer field season. By the end of the field period the arcing had been corrected and no evidence of that problem appeared in 1977.

The digital processor errors were not found until the summer season had been completed. Eventually, it developed that the errors had steadily increased in frequency during the season. The lack of any quality control technique in 1976 led to the errors remaining undetected during the field season.

Six of the 1976 days were sufficiently error-free to permit cleanup of the tapes. This required the development of a quality control and error-checking system for use on the computer. A large portion of the errors could be identified and corrected by the computer. The remainder had to be examined and corrected by hand. The tape from one of these days (May 21) was sent to North Dakota for a check of its readability within the framework of the Bureau processing system. This tape was returned with a few minor reading problems.

Table 1

SNYDER RADAR DATA - 1977

Date		Time (CDT)
June	1	0932-1957
	8	1115-1230
	9	1340-0140 (10th)
	11	1415-0352 (12th)
	13	2347-0129 (14th)
	20	2000-0200 (21st)
	21	1225-0200 (22nd)
	22	1102-0031 (23rd)
	23	1401-2112
	24	1250-0155 (25th)
	25	1100-0155 (26th)
	26	1644-2055
	27	1524-2309
	28	2245-0111 (29th)
	30	1525-2314
July	7	2009-2300
	8	0938-2033
	9	1252-2055

Table 2

CLOUD BASE AIRCRAFT SAMPLING - 1977

Date		Flight Times (GMT)
June	1	2025-2147
	9	2055-2305
	11	2050-2250
	12	0025-0145
	21-22	2250-0055
	23	2015-2240
	25	2059-2308
July	8	1922-2203
	15	1328-1439

Much of the processing time during June, July and August was spent in rapid quality control checks of the 1977 field tapes in order to identify errors in time for corrective action. The 1977 processor errors were significantly reduced by this system. After the field program was completed all of the field tapes were converted from 1600 bpi to 800 bpi in order to conform to the Bureau format.

In September, the MRI radar processing responsibilities were given to Dr. A. H. Vanderpol who is in charge of the data processing section at MRI. Late in the month Dr. Vanderpol visited North Dakota and the Bureau to determine the optimum method for entry of the Texas radar data into the Bureau system. As a result of these discussions, several possible improvements in efficiency have been identified and the processing should be carried out more effectively in the future.

3.2 Radar PPI Plots

A software program was written to plot iso-contours of reflectivity for each low-elevation scan of the antenna. All of the 1977 data have been processed in this manner at one-half hour intervals while the radar was in operation. Samples of these plots are shown in Figures 1-4 which indicate the passage of an active squall line through the Big Spring area. Similar plots were made for all available data on June 22-23 and July 10-11, 1976.

3.3 Mechanical Weather Station Data

Ten Mechanical Weather Stations were operated in and near the project area during the field season. At the end of the summer the charts from these stations were processed into hourly records of wind speed, direction and temperature for each of the ten stations. These data were then put on magnetic tape and sent to Texas A & M.

4. Data Analysis

4.1 Static Energy Maps

The surface station data for June 22-23 and July 10-11 have been analyzed in terms of hourly surface static energy at each of the ten stations as well as at Lubbock, Midland, Abilene, Webb and San Angelo. Surface static energy consists of a summation of terms resulting from internal energy, latent heat and a geopotential component. The static energy value is altered by radiative changes but is relatively invariant to lifting, subsidence or evaporation effects.

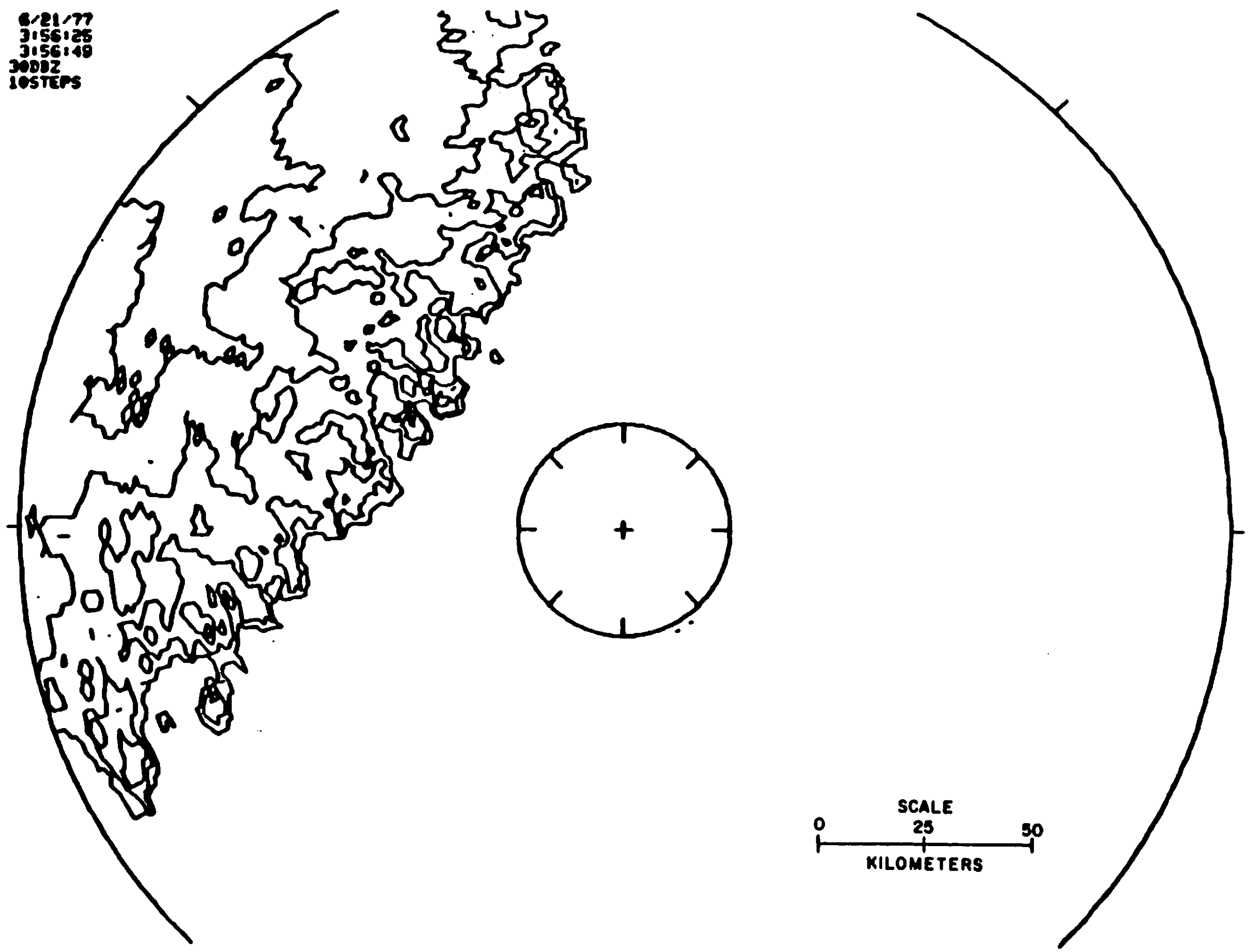

Figure 1. PPI Radar Plot
0356 GMT - June 21, 1977

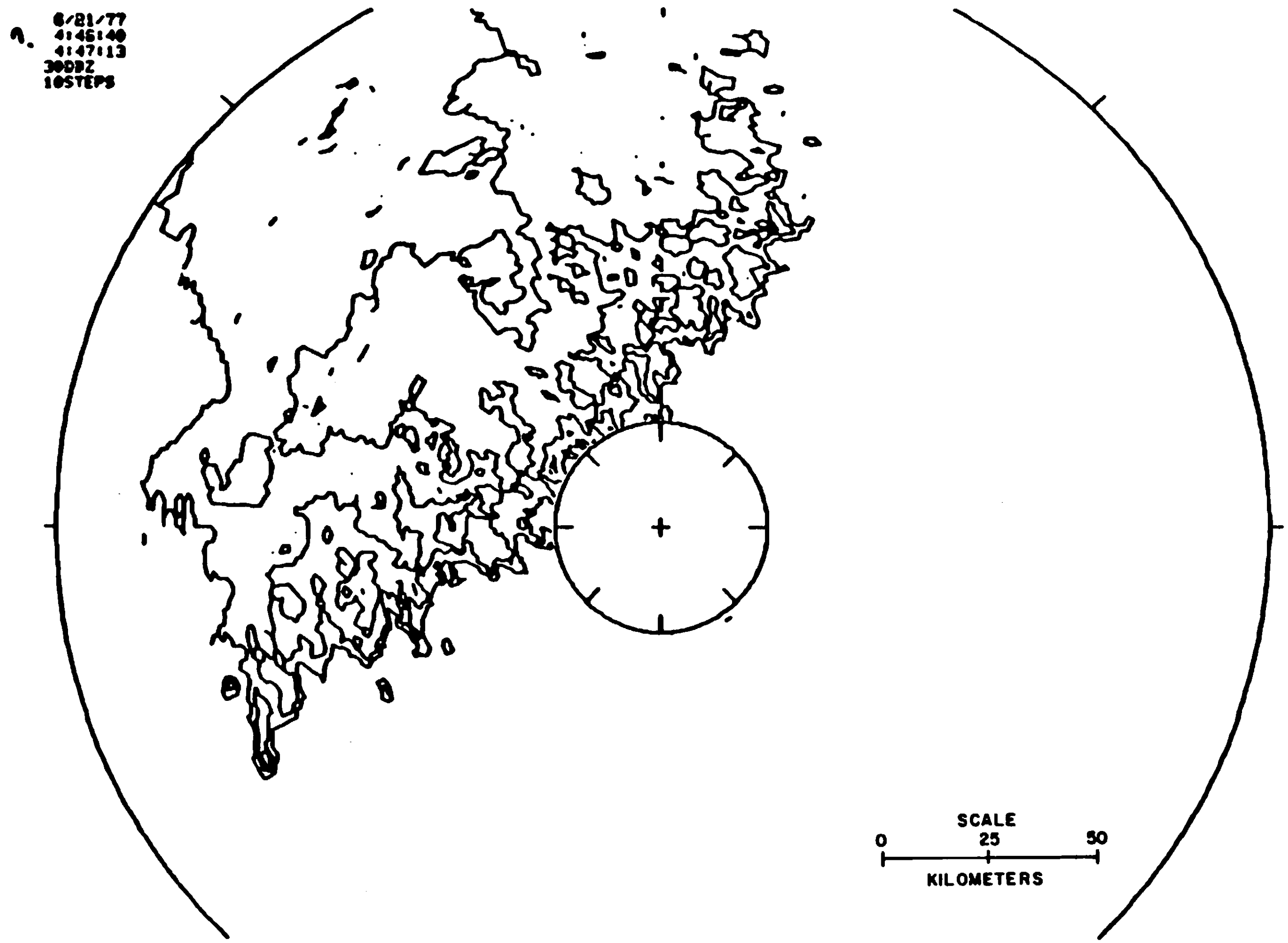

Figure 2. PPI Radar Plot
0446 GMT - June 21, 1977

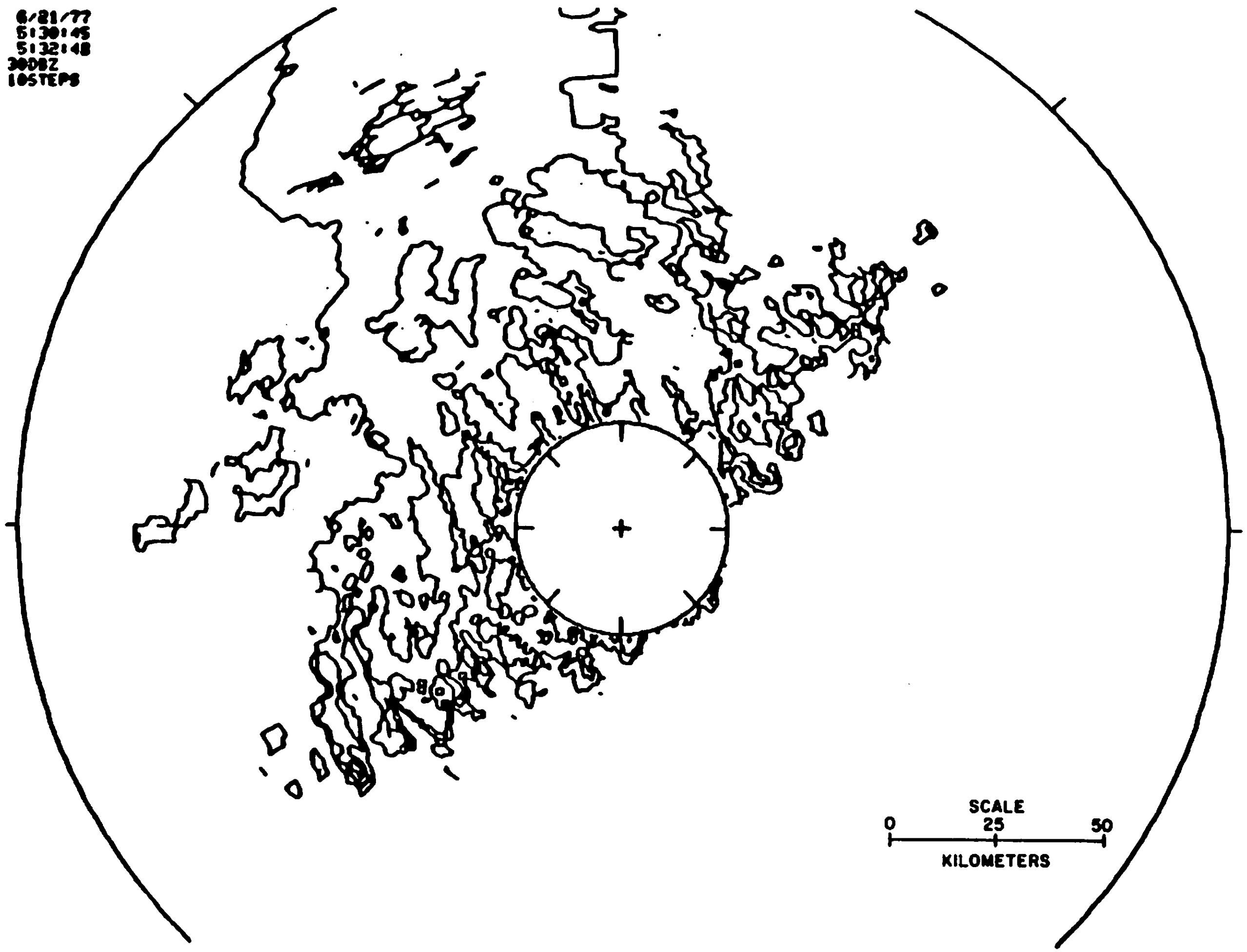

Figure 3. PPI Radar Plot
0530 GMT - June 21, 1977

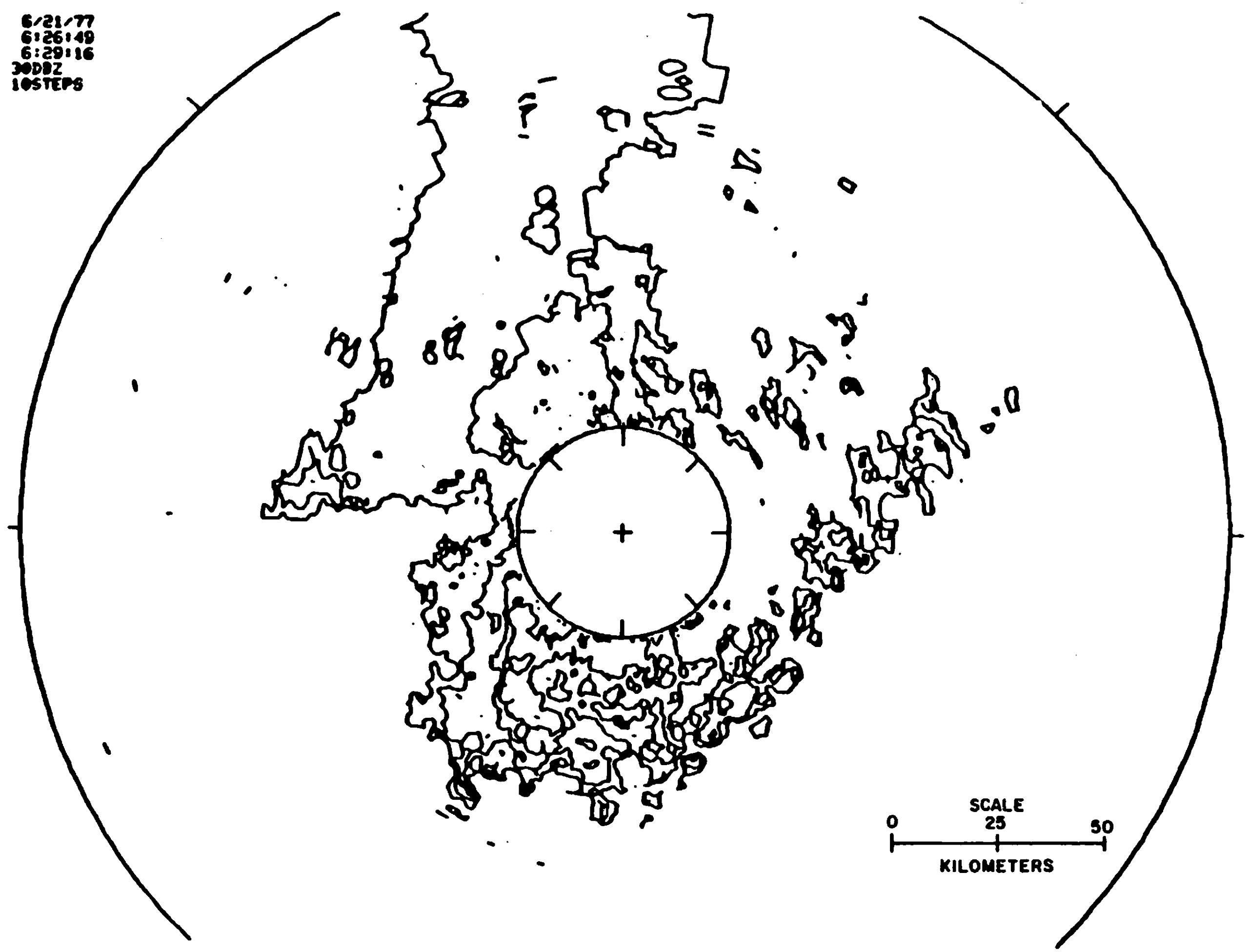

Figure 4. PPI Radar Plot
0626 GMT - June 21, 1977

The rainfall system on June 22-23, 1976 consisted of an organized line which formed in eastern New Mexico, passed through Lubbock near 1800 CDT and passed Snyder between 2100 and 2200 CDT. Four of the hourly static energy maps for June 22-23 are shown in Figures 5-8. PPI radar plots of the organized line at 2100 and 2300 CDT are given in Figures 9-10. The boundary of the cold air associated with the system downdraft is shown moving toward the southeast and represents a region of marked gradient in static energy. Generally high values occur on the warm side of the outflow boundary. The cold air of the downdraft is characterized by much lower values of static energy. The positions of the center of the radar echo line at 2100 and 2300 CDT are shown on Figures 6 and 8, respectively.

Since the radiative effects on static energy do not operate significantly over such short time or distance scales, it is useful to try to find the source of the much lower static energy values apparent within the cold air. An examination of the static energy values found in nearby rawinsonde observations shows that the only source of the low static energy values (or 330 J/g) is in the height range of 600 to 500 mb. This layer then appears to provide the source of much of the cold downdraft air. The cold air front in Figure 6 is shown to be parallel and a short distance ahead of the radar echo line. At the same time, the echo patterns in Figure 9 show pronounced activity along the entire line. By 2300 CDT the cold air front was located considerably in advance of the line while the distance from the front to the radar line in the Robert Lee area was much smaller. It is of interest in Figure 10 that the most significant rainfall activity appeared to be occurring near the southern end of the radar line.

A problem of major interest in this situation is the mechanism for propagation of the squall line from eastern New Mexico into the Big Spring area. In many cases, of which this case is typical, the squall line begins to dissipate in or east of the Big Spring area during the early morning hours. The mechanism of dissipation may be that the cold air outruns the squall line or that the surface static energy levels may decrease during the nighttime so that adequate low-level energy sources are no longer available to feed the storm. Knowledge of these mechanisms will permit the formulation of hypotheses for possible modification of the squall line to increase its lifetime.

4.2 Time Analysis of Rainfall in the Big Spring Area

The observations as given in the previous section on significant rainfall during the nighttime hours in the Big Spring area have led to an examination of diurnal rainfall patterns. Hourly rainfall values for Big

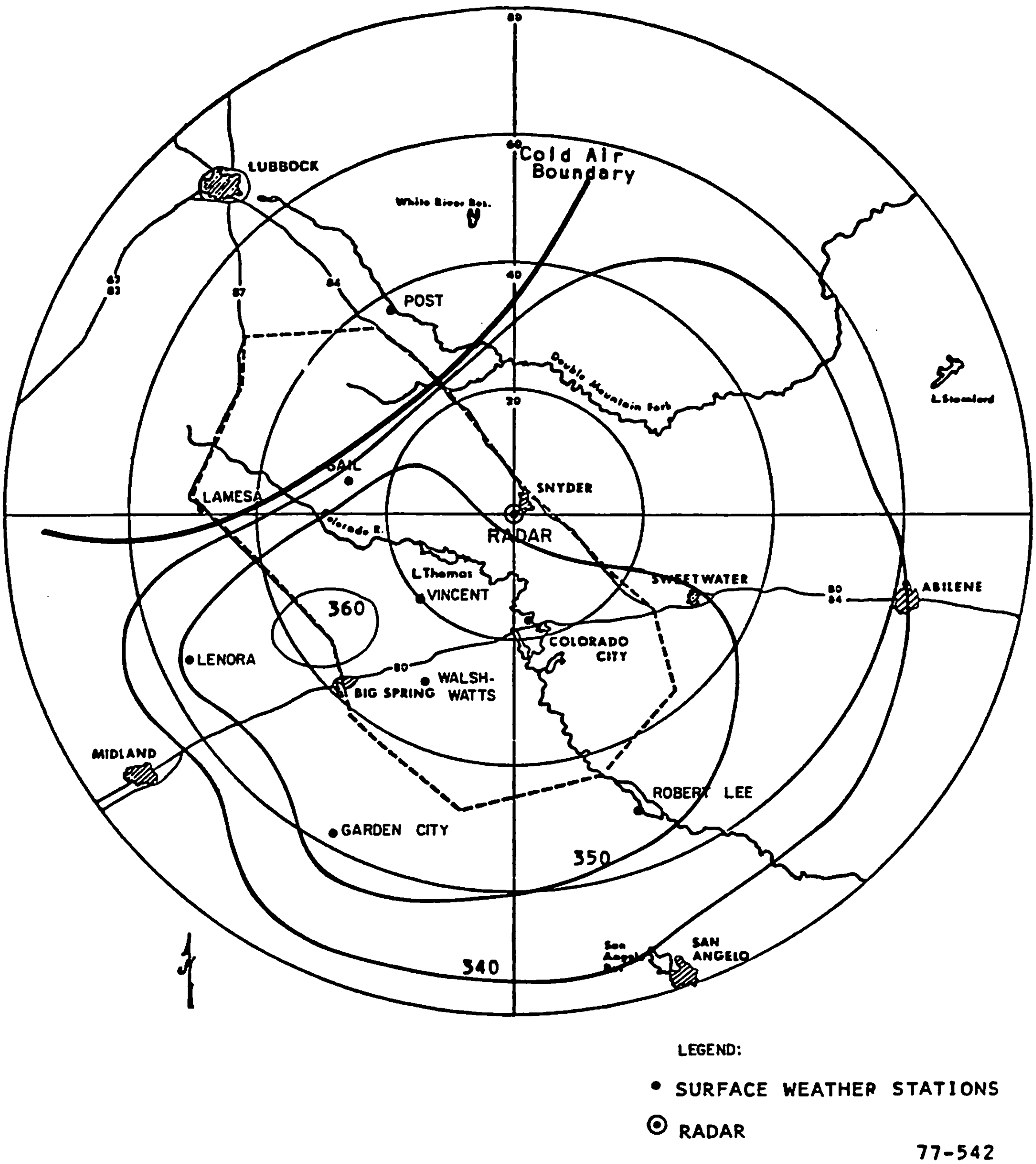

Figure 5. Static Energy (J/g)
2000 CDT - June 22, 1976

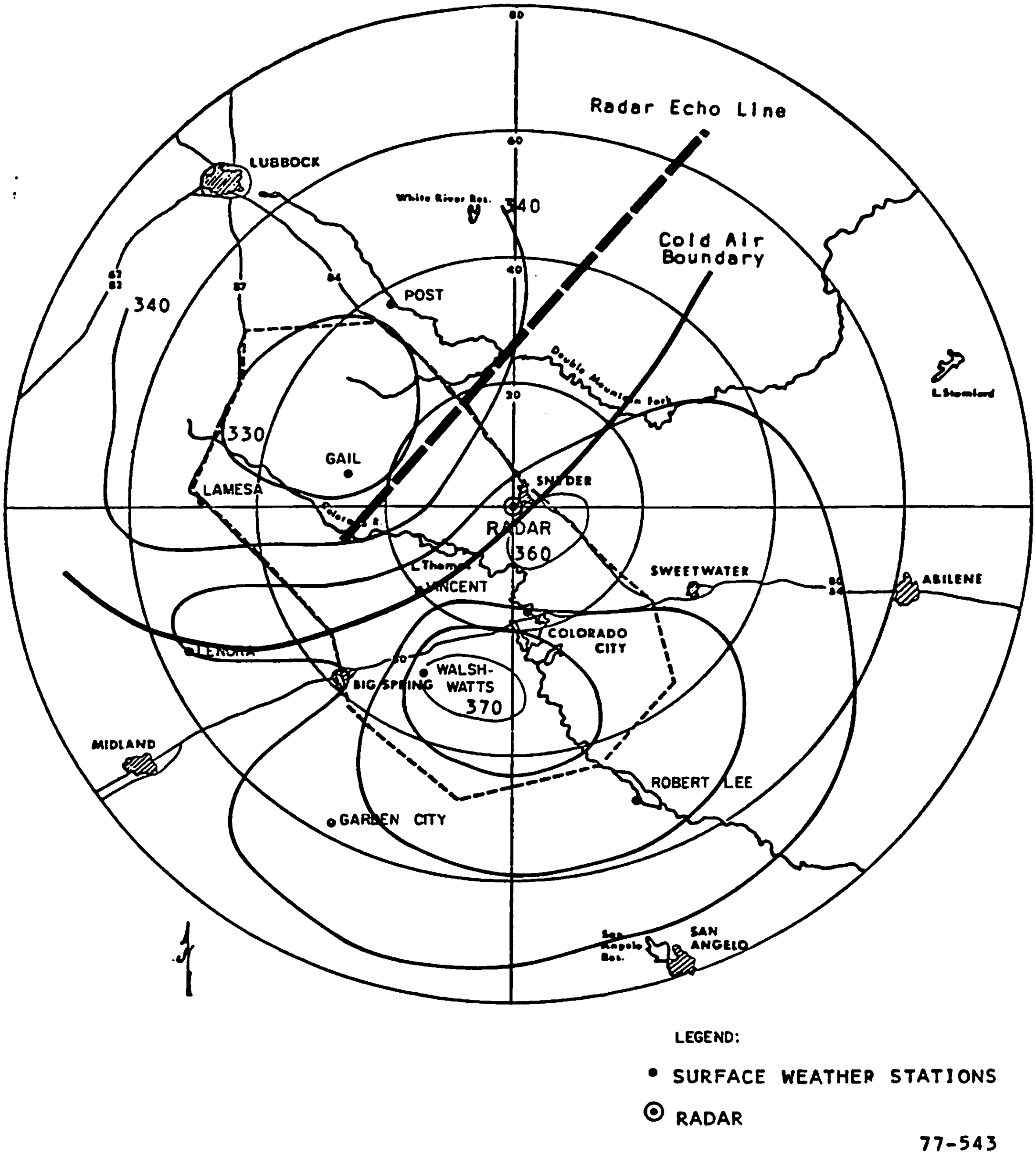

Figure 6. Static Energy (J/g)
2100 CDT - June 22, 1976

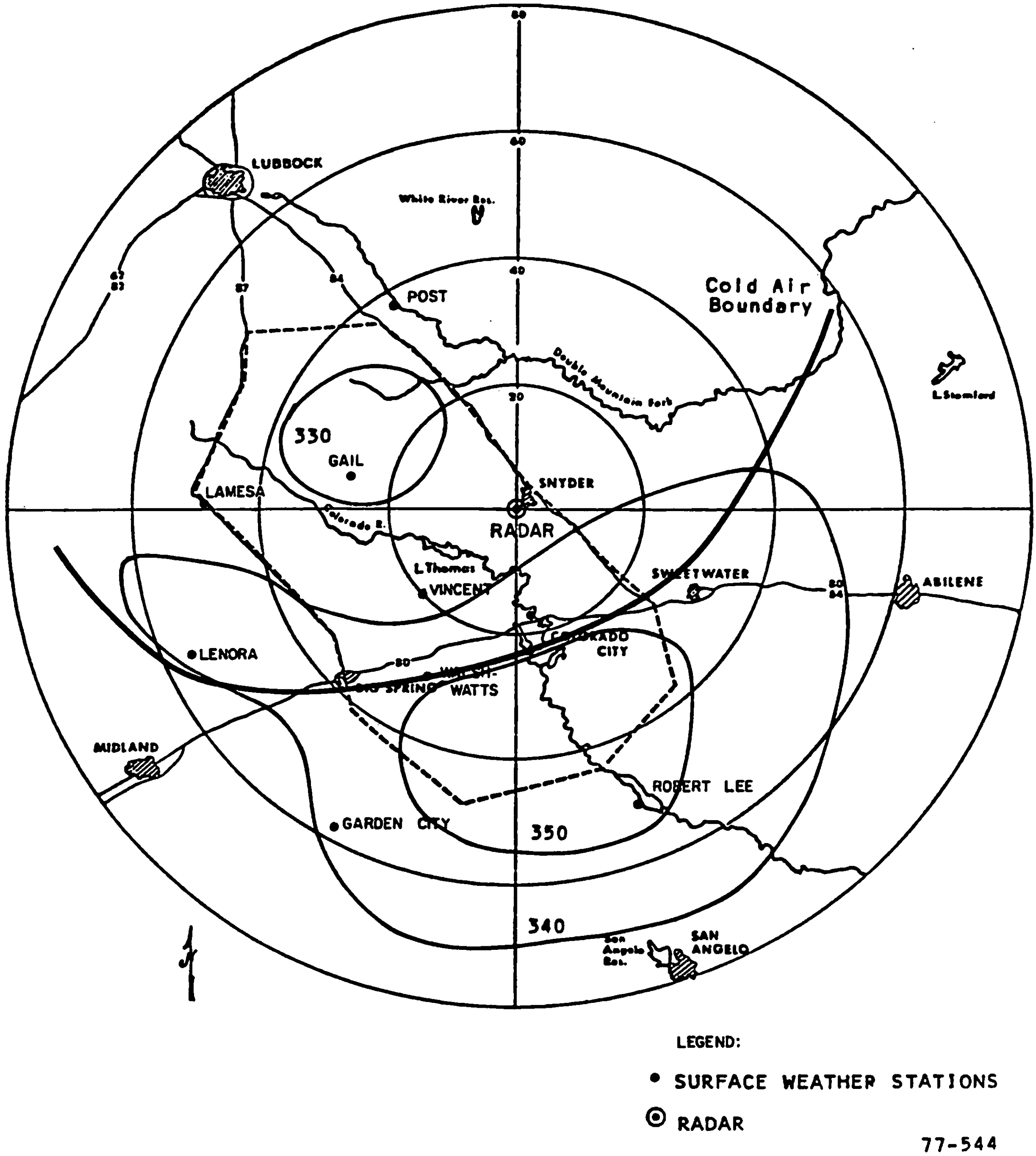

Figure 7. Static Energy (J/g)
2200 CDT - June 22, 1976

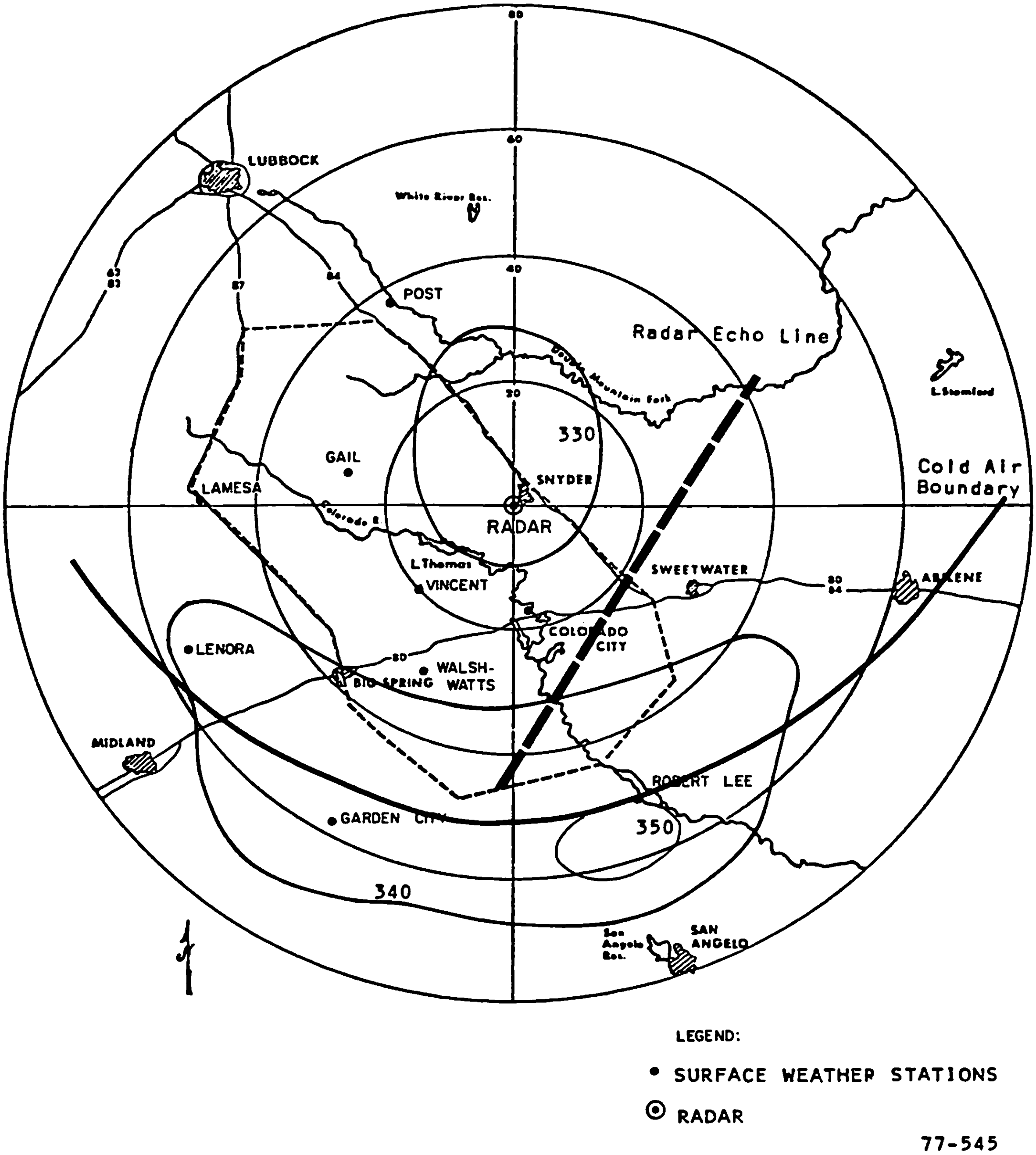

Figure 8. Static Energy (J/g)
2300 CDT - June 22, 1976

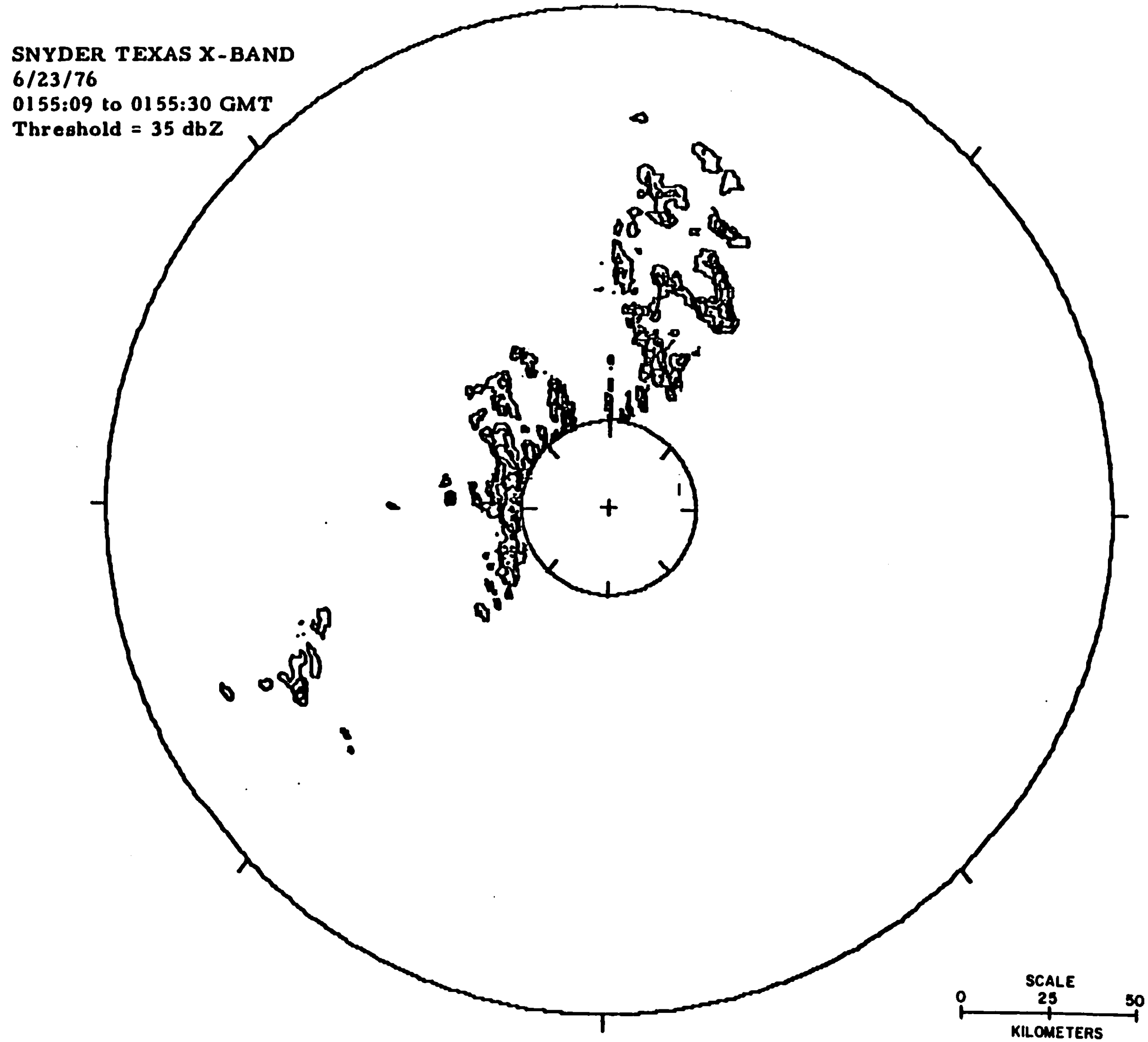

Figure 9. PPI Radar Plot
0155 GMT - June 23, 1976

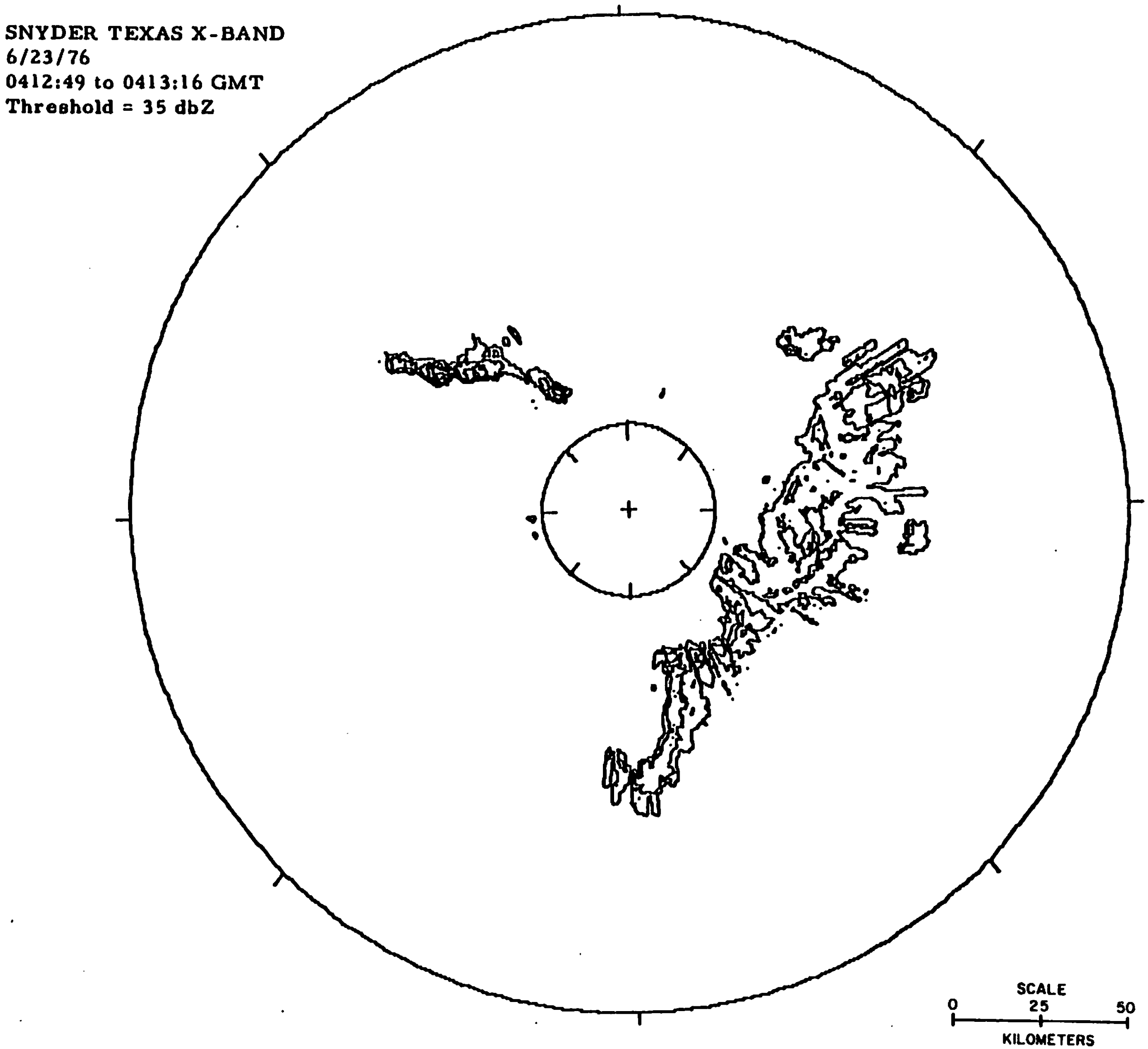

Figure 10. PPI Radar Plot
0412 GMT - June 23, 1976

Spring Field Experiment Station (slightly north of Big Spring) and Lake Colorado City were used in the study. A total of seven years (April thru September) were employed for the study. Data from 1964 through 1969 were available at Big Spring Field Experiment Station. The year of 1972 from Lake Colorado City was added to obtain a larger sample. The lack of long-period records of hourly rainfall area limited the sample size that could be examined.

Table 3 summarizes the results of the study. The first column in the table shows the total number of occasions (seven-year period) when rainfall of at least 0.01 inch occurred in the hour indicated. The second column gives the total rainfall in the seven-year period which occurred during the hour indicated.

Both columns indicate a double diurnal maximum at about 0100-0200 CST and from 0700 to 0800 CST. There is also an indication of a smaller maximum at around 1800-1900 CST. The principal impression to be drawn from the table is that the rainfall is distributed much more uniformly throughout the day than would be expected if the usual diurnal convective influences were the principal mechanism involved. The data suggest that many of the seeding opportunities probably occur during the nighttime hours when sampling flight operations cannot be carried out as effectively.

4.3 Hailstone Analysis

On 24 May 1975 a hailstorm passed over the Lake Thomas drainage basin. Many hailstones in excess of 4.0 cm in diameter were collected in the immediate area of the Lake Thomas dam. A short distance away, in Ira, many more hailstones of one cm and smaller were also collected. These hail samples were dipped in chilled hexane to assure all stones were completely frozen and then stored in sealed containers to inhibit sublimation. The hailstones were then sent to NCAR in Boulder, Colorado for analysis.

The object of the analysis was to determine the embryo type at the center of each stone which would help in understanding the hail forming mechanism in the 24 May storm.

The Texas hailstones were sectioned in the cold room at NCAR under the direction of Dr. N. Knight. The procedure was as follows. Each stone was sawed in half along the axis of the internal conical structure if one was evident. This maximized the chance of sectioning the embryo. Each half of the hailstone was visually inspected to select the half which provided the best section of the embryo. Saw abrasions were then removed using a

Table 3

DIURNAL RAINFALL CHARACTERISTICS IN THE BIG SPRING AREA

SEVEN-YEAR PERIOD (APRIL - SEPTEMBER)

Hour Ending (CST)	Total No. Rain Events	Total Rainfall for Period (inch)
0100	28	4.63
0200	40	6.36
0300	39	4.45
0400	30	2.09
0500	28	2.23
0600	28	2.39
0700	25	3.15
0800	33	4.73
0900	43	4.66
1000	34	3.43
1100	29	2.05
1200	22	1.20
1300	26	2.96
1400	29	2.75
1500	32	3.15
1600	34	3.36
1700	32	2.48
1800	29	3.16
1900	33	4.74
2000	32	3.57
2100	27	1.97
2200	31	3.32
2300	23	2.26
2400	23	2.69

coarse file. By pressing the polished surface against a heated glass slide, the stone half was fastened to the slide. Care was taken to ensure no air was trapped between the slide and the stone. After the stone was frozen securely to the slide, the bulk of the hailstone was removed using the band saw, leaving a section of the hailstone approximately 2 mm thick. Once again abrasions were removed with the coarse file. Final polishing of the section was performed by rubbing with a gloved hand. The heat of friction and body heat were sufficient to melt a thin layer of the section and provide a high lustre. The prepared slide was then examined under a microscope and photographed. When transilluminated with normal light the rings representing the various growth regimes are quite clear. If a clear spherical or hemispherical center is apparent the hail embryo is considered to be a frozen raindrop. If a definite conical shape of opaque ice with no definite center is observed, the embryo is considered to be graupel. Many specimens are difficult to categorize from the normal light photo alone. In order to assist in the identification of embryo type in these cases, a second photograph using polarized light is often made. In this technique a second polarizer is introduced between the slide and the camera lens. Single crystals are then easily identifiable due to the coloration introduced. Single crystals, or a few large single crystals near the center are characteristic of raindrop embryos; many small crystals near the center are characteristic of graupel embryos. Since the colors are adequately recorded as different shades of grey, on black and white file, color film for crystal structure identification is rarely used.

Of the 81 stones analyzed from the 24 May storm 73 contained graupel, 2 contained raindrop and 6 contained unknown embryos. The strong predominance of graupel is contrary to earlier evidence from San Angelo suggesting raindrops predominating in the early stages of Texas storms. The 24 May storm however was without doubt a rather severe storm with large updrafts. This is evidenced by the fact that the median hailstone size in the Lake Thomas dam area was near 4.0 cm. With large updrafts there is little time for raindrops to grow and thus graupel formation may predominate. In more moderate storms it seems likely that frozen raindrops may contribute significantly to the precipitation mechanism.

TEXAS A&M UNIVERSITY

"MESOSCALE FIELD PROGRAM AND INITIAL DATA ANALYSIS"

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The work described herein covers the mesoscale experiment conducted in the Big Spring-Snyder area of Texas during the summer of 1977 and analysis of the data collected during the summer of 1976.

MESOSCALE FIELD PROGRAM

The mesoscale field program extended from June 1 through July 12, 1977. Because of very favorable weather conditions during this period, July 10 was the last day on which soundings were taken, and the collection of data from the special surface stations ceased on July 12. Sounding data were collected on 12 days during June and on four days during July. In particular, soundings were made at 1 1/2 hr intervals on two days during June and on one day during July. No major problems were encountered during the observational program and, in contrast with the summer of 1976, very little data were lost due to equipment malfunction.

1. Special Instrumentation and Data

As during the summer of 1976, microbarographs were borrowed from Texas Tech University, a rawinsonde unit was obtained on loan from the U.S. Army, and soundings were purchased from the National Weather Service (NWS) office at Midland. Hygrothermographs were purchased by Texas A&M University and used in the field program.

These acquisitions were a major improvement upon equipment used in the 1976 field experiment. Arrangements were made with NWS personnel at Midland to obtain radar logs and Plan Position Indicator traces of all convective echoes in the Texas HIPLEX region during the experimental period, and to acquire surface data routinely collected at Midland by the NWS. Teletype and facsimile data were collected at Texas A&M University and placed in archives for future reference.

Arrangements were made with the Colorado River Municipal Water District (CRMWD) to use their facilities at Robert Lee to house a rawinsonde unit and with a private individual at Post, Texas for rental of space to house a second rawinsonde unit. These arrangements were extremely satisfactory, as the facilities proved to be adequate. In addition, the CRMWD provided necessary office space for our personnel in Big Spring and assisted with communications problems.

2. <u>The Operational Program</u>

The 1977 mesoscale experiment was conducted in a similar fashion as the 1976 experiment with a few improvements. The ten surface stations and the four rawinsonde stations were installed in the same locales as before. New hygrothermographs purchased by Texas A&M University were calibrated in advance of the field program and were operated almost flawlessly during the entire period of the experiment. An electronics technician was employed to be on location to handle any equipment problems which were incurred. Three major problems arose with the rawinsonde equipment, once at Robert Lee and twice at Post. These problems were corrected within a matter of hours and only two soundings were lost because of equipment malfunction. All sounding data were coded in the field on a daily basis and forwarded to Texas A&M for keypunching. In addition, data were extracted from the strip charts of the ten surface stations and forwarded to Texas A&M University for keypunching. This procedure eliminated the need for considerable data adjustments and made the overall operation far more efficient than during the summer of 1976.

Upon termination of the field experiment, all equipment was returned to the appropriate locations, and the field personnel returned to College Station to continue data processing and analysis activities.

3. Data Processing and Initial Analysis

At the conclusion of the field program, all field personnel continued the tasks of extracting data from the strip charts and keypunching and checking all of the data for errors. By the end of the summer, all data had been extracted, keypunched, and checked for errors and certified to be correct. Time cross-sections and constant-pressure charts were prepared for the various parameters of the surface and sounding data and analyzed to insure time and space continuity. Data were extracted from the soundings and keypunched in the form required for use by the Bureau of Reclamation's computer. A data report and magnetic data tapes could not be prepared by the end of this report period, since surface wind data were not available at that time. In addition, data for the Bureau could not be provided because they also require the missing surface wind data. These tasks will be completed early in the next report period after the surface wind data are received from Meteorology Research, Inc. The sounding and surface data will be made available in a data report as well as on magnetic tape in the same format as used for the 1976 data.

DATA ANALYSIS

1. Energy Study

This study was completed for all days for which sounding data were available. The kinetic energy budget, which was examined in detail, included transformations of energy from one form to another. In addition, the study included an analysis of the latent heat energy budget to examine the energy source for convective storms. It was found in these studies that the storms interact appreciably with the environment, with the atmosphere initially being responsible for the initiation and growth of the activity while, in the mature stages, the same thunderstorms invluenced the environment. This study is expected to be a major source of information for the development of seedability models.

2. Surface

The surface data were objectively analyzed by computer and fields of parameters such as moisture divergence, vertical motion, vertical moisture flux, and vorticity were analyzed at 1-hr intervals for a 12-hr period beginning at 1500 GMT on days when significant convective activity occurred. These data are being analyzed to determine characteristics of the surface layer associated with the formation, maintenance, and dissipation of convective activity. This study tentatively shows a high correlation between conditions reflected in the surface data and convective activity. There appears to be little doubt that results from this particular study will prove to be very useful in determining where and to what extent convective activity will form.

3. Radar

Radar data from the National Weather Service station at Midland were coded in grid form, keypunched, and plotted computer. These data have proved to be invaluable in the analysis of both surface and upper-level conditions.

4. Rainfall Data

All fence post and recording rain gage data were plotted on charts but were not analyzed. While the rainfall data must constitute a major concern in our analysis, it was decided that the analysis of the data would be conducted by Texas Tech University and Meteorology Research, Inc. Because of the sparseness of the rain-gage network, it will be necessary to incorporate radar data in order to provide an adequate rainfall analysis.

TEXAS A&M UNIVERSITY

"RADAR-ECHO CLIMATOLOGY FOR THE

SOUTHERN HIPLEX REGION"

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The objectives of this program are to construct a radar-echo climatology for southern HIPLEX and to differentiate the characteristics of this climatology for both seeded (target) and proximate, unseeded areas. These characteristics are:

- Geographical occurrence of initial echo formation and migratory echoes;
- Annual, monthly, and diurnal variations in each occurrence;
- Durations of echoes to 8-km diameter and to maximum size;
- Speed and direction of movement of the echoes.

Plan Position Indicator (PPI) photographs from the National Weather Service WSR-57 radar at Midland were obtained for the periods April through September of 1973-1976. A 16-mm, stop-action, variable-frame-speed projector was obtained and used in the data-acquisition phase of the study.

A wedge-shaped area was delineated for analysis (Figure 1) and a grid pattern was overlain (Figure 2). A form was prepared for data entries (Figure 3). The data reduction phase of the work, i.e., the transcription of data from the PPI photographs to the form, was accomplished by running the film ahead in time at various speeds and recording the various characteristics listed above. In addition to the Principal Investigator and a graduate

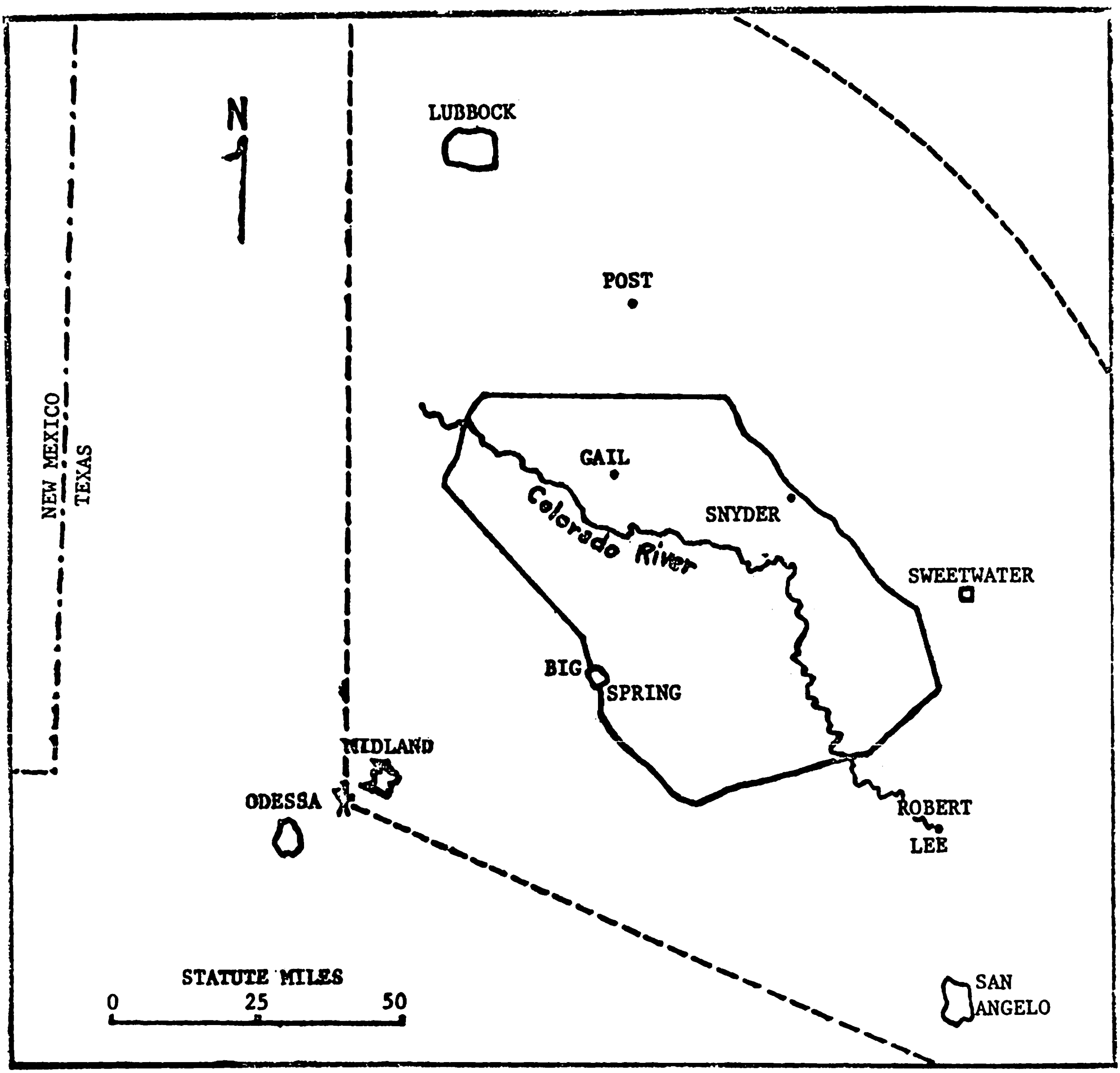

Figure 1. Area of Southern HIPLEX region for which a radar-echo climatology is being prepared.

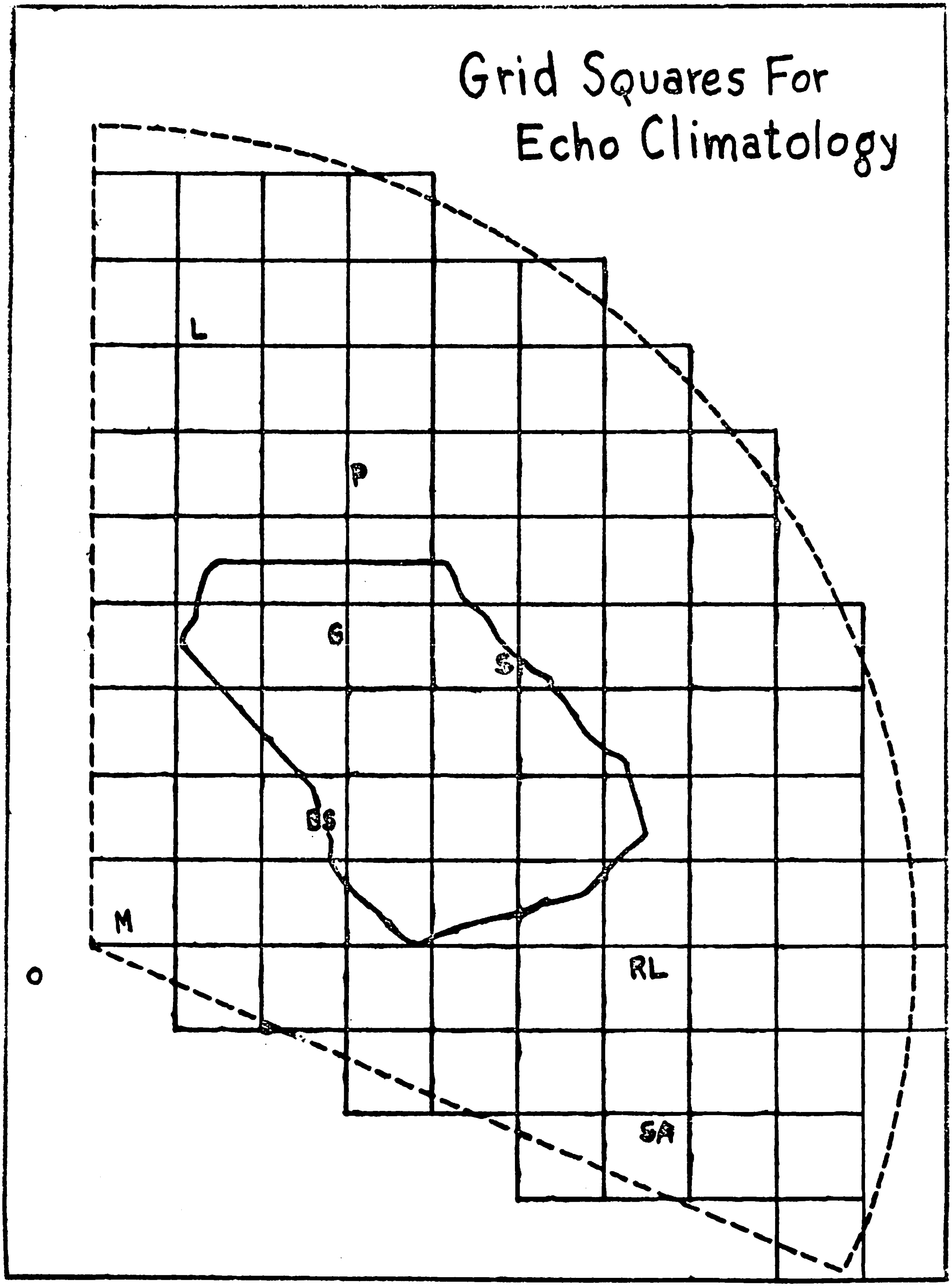

Figure 2. Grid Squares for the Data-Acquisition Phase of the Radar-Echo Climatology.

RADAR DATA WORKSHEET

JULIAN DAY	YEAR	MONTH	DAY	FILM FRAME	GMT HOUR	ECHO NO.	ECHO OBS. NO.	GRID LOCATION	ECHO LENGTH (KM.)	ECHO WIDTH (KM.)	ECHO RADIUS (KM.)	NO. CELLS IN ECHO	ECHO ORIGIN	GRID SQUARES AFFECTED	DURATION CODE	REMARKS

TWDBE-WM&T-10

Figure 3. Radar Data Worksheet Form.

assistant, four technical assistants were employed in the data reduction. This process, which required considerably more time than was initially expected, was completed in mid-August after a total of about 650 man-hours was expended.

In terms of fulfilling the objectives of this study, two exceptions are noted. Firstly, as described in the June 1977 monthly progress report, it has not been possible to specify the size of initial echoes. Secondly, a sampling procedure had to be utilized to determine durations of echoes. Following every echo to its demise proved to be impossible. So, of every ten echoes, one was followed to 8-km in diameter, and another to its maximum size. The echoes that were followed were chosen randomly to produce an unbiased sample.

TEXAS TECH UNIVERSITY

"SATELLITE-DERIVED CLOUD CLIMATOLOGY

FOR THE SOUTHERN HIPLEX REGION"

Efforts during the period April 1 - September 30, 1977 in support of the Texas-HIPLEX program consisted of the following four activities:

- Selection for analysis of intensive case study days during 1976;
- Development of techniques for processing, displaying, and analyzing satellite radiance data;
- Acquisition of photographic imagery of the 1977 Texas-HIPLEX field period; and
- Summarization of available satellite data for summer cloud characteristics.

Four days were selected as 1976 intensive case study days: June 3, June 22, and July 1. These days were selected on the basis of maximum availability of satellite radiance data, upper air soundings, and weather-radar data. The June 22-23 2-day period is the first to be studied, with the other days to be analyzed next.

An important part of the work was the cooperative arrangement developed with Colorado State University. Use of the digital data display system contributed significantly to the work accomplished during the period. The system provided an opportunity of quickly looking at a region of a data tape, overlaying visible and infrared data sets, performing both black-and-white and color enhancements, and observing cloud motion through rapid viewing of data sets at successive times.

In addition to this tool, techniques were developed or adopted to preprocess the raw data tapes, locate and correct bad data elements, convert visible data into albedo and also infrared data into temperature, and to summarize cloud properties by cloud number, size, brightness, and temperature. The synthesis of these results in time sequence constitutes the analysis procedure for intensive case studies of the satellite data. During analyses of the radiance data, comparisons using both the upper-air and radar data were made to verify the correctness of the satellite results as well as to determine differences between the various observation platforms.

During the period June 1 - July 15, 1977, photographs obtained from GOES images were gathered on a 24-hour basis at the National Weather Service Forecast Office in Lubbock. During daylight hours photographs alternated between visible and enhanced infrared and, at night, between infrared and enhanced infrared, both at one-half hour intervals between images. The 90,000 km^2 Big Spring study area was examined for cloud type, number, cloud top temperature, and movement.

TEXAS TECH UNIVERSITY

"PRECIPITATION CLIMATOLOGY FOR THE

SOUTHERN HIPLEX REGION"

An effort to develop a precipitation climatology for the Texas HIPLEX region was begun by a team of Texas Tech University researchers on May 5, 1977 and continued for the duration of the reporting period.

Monthly precipitation data for the period 1944-1977 were collected, entered on computer cards, and subsequently transferred to magnetic tape. All available data were acquired from National Weather Service first and third-order stations in or near the HIPLEX study region. Based on these data, maps depicting mean monthly precipitation were constructed for the Texas HIPLEX area. The spatial variation of monthly rainfall totals was investigated further by computing a coefficient of correlation between each pair of stations for each month of the period. By using rainfall totals for a month, it was possible to determine averages of the magnitudes and paths of storm systems covering the area. Correlations are expected to be below those for individual storms, but the results should give information on the average sizes and paths of the storms.

An analysis of daily precipitation events was completed for the entire period of record of stations at Lamesa, Snyder and Big Spring. Frequency distributions were computed for the number of rainfall periods per month and for the amount of rain associated with an individual rainfall period. As expected, rainfall periods were associated with widely differing amounts of rain. Both the size distribution of rainfall occurrences and the frequency of rainfall periods were observed to be highly variable from month to month. Most of the rainfall periods brought less than 1/2 inch of rain. Rains of 2 inches or more were seen to be much less common but nevertheless are distinctive features of the rainfall distribution and exert considerable influence on the average precipitation distribution for the region.

Development of a 10-year climatology of weather events, which will form the basis for an investigation designed to define precipitation patterns associated with specific meso-synoptic events, was completed in September, 1977. The diurnal distribution for all reported weather events was tabulated for each month for stations at Abilene and Midland, Texas.

COLORADO RIVER MUNICIPAL WATER DISTRICT

"HIPLEX RAIN-GAGE AND RAWINSONDE SUPPORT PROGRAMS"

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In support of the 1977 Texas-HIPLEX Program, the Colorado River Municipal Water District maintained and monitored an extensive network of recording and non-recording rain gages, operated an RD-65 rawinsonde unit, and provided the services of a radar meteorologist during the period April 1 - September 30, 1977.

CLOUD-SEEDING ACTIVITIES

In addition to the services rendered in support of the HIPLEX Program, the District's privately-sponsored cloud-seeding program to supplement surface water runoff into reservoirs owned and operated by the District was conducted during the same period. The District conducted a total of 51 flights during the 6-month period, 42 of which were flights during which cloud-seeding was performed (Table 1). May and June were the most active months for cloud-seeding activities.

Compared with the other six years during which the District has been conducting its weather modification program, the 1977 cloud-seeding season was only slightly above the 6-year mean in terms of number of cloud-seeding flights conducted (Table 2). The nine flights performed in April 1977 marked the most activity during the month of April since the program began in 1971. For only the second time in the past seven years, no flights were conducted

TABLE 1

CRMWD MONTHLY WEATHER MODIFICATION FLIGHT SUMMARY

1 APRIL - 30 SEPTEMBER 1977

	Flt. Time (Hrs.)	Seed Time (Hrs.)	No. Flts.	Seed Flts.	AgI (gm)
April	16.1	8.3	11	9	1520
May	24.4	13.5	14	10	2840
June	19.2	10.2	14	10	2920
July	11.4	5.3	7	4	1200
August	11.0	4.2	4	9	1540
Sept	.7	-0-	1	-0-	-0-
TOTAL:	82.8	41.5	51	42	10020

T A B L E 2

HISTORICAL SEEDING FLIGHT SUMMARY

SILVER IODIDE CASES ONLY

	April	May	June	July	Aug	Sept	Oct	Total:
1971	5	14	9	2	7	3	1	41
1972	6	7	10	9	12	4	0	48
1973	5	7	9	14	10	5	1	51
1974	3	3	2	3	6	0	0	17
1975	2	5	3	13	6	1	0	30
1976	8	9	6	13	7	6	2	51
1977	9	10	10	4	9	0	N/A	42
Average Number of Seeding Flights	5.4	7.8	7.0	8.2	6.7	2.7	.6	

during September.

Cloud census data were collected by the District's radar meteorologist using the 3-cm radar system at Howard County Airport near Big Spring. Data were collected during all operational periods and whenever significant weather was observed in the area. The data described the location and movement of radar echoes, the radial measurements of most intense echoes, and the heights of cloud tops. The data were usually obtained and recorded at 15-minute intervals. Cloud census data ordinarily were not collected in situations when the meteorologist believed radar cells observed on the radar would not develop within or move into the cloud-seeding target area; however, on those occasions, routine survey scans were made with echo locations being recorded on 16-mm film as in the same manner as that followed when cloud-census data were being recorded.

For each reconnaissance or cloud-seeding flight, the District's aircraft pilot logged data on cloud-base heights and temperatures, updraft sizes and velocities, and verticle temperature profiles of the atmosphere for each operational period. In addition, a brief written description on each flight was prepared and submitted by the pilot.

The cloud-census data and the aircraft pilot's logs for each of the months during which cloud-seeding operations were conducted during 1977 accompanied the monthly progress reports which the Department submitted to the Bureau. A summary of the data collected by the District's aircraft pilot is presented as Table 3.

RAIN-GAGE NETWORKS

The Texas-HIPLEX recording rain-gage network was maintained and monitored throughout the 1977 Texas-HIPLEX Program by District personnel. In addition, the District maintained its own rain-gage network consisting of 81 fence-post, non-recording rain gages which were located at approximately 3-mile intervals along major roadways within the District's target area. A District rain-gage technician made readings of these gages each time precipitation was observed to have occurred over the area.

The recording rain-gage network consisted of Belfort and Fischer-Porter rain-gages located approximately ten miles apart within the District's watershed. One non-recording, fence-post rain-gage owned by the District was placed adjacent to each of the recording rain gages, and these fence-post gages were read every seventh day--whenever the recording rain-gages were serviced.

Hail pads were not used at any time during the 1977 program.

The recording rain-gage data were forwarded periodically to the Bureau for processing. A listing of the non-recording rain-gage data was provided the Bureau each month along with the Department's monthly progress report.

The following is a listing of the types and number of rain gages used to collect rainfall data in the Texas-HIPLEX

T A B L E 3

1 APRIL - SEPT. 30, 1977 CRMWD OBSERVED CLOUD SEEDING DATA

DATE	TIME (LDT)	FLT.#	MISSION	SEED TIME	CLOUD BASE TEMP. (°C)		CLOUD BASE HT. (K FT.)		MAXIMUM UPDRAFT Ft/Min	HORIZONTAL EXTENT N. Mi.	AgI DISPENSED (gm)
					Min.	Max.	Min.	Max.			
4-14-77	1045-1216	1	Seed	1123-1152	-1	-1	9	9	.5	2	180
4-14-77	1219-1250	2	Recon	---	9	9	4.5	4.5	---	---	-0-
4-14-77	1355-1510	3	Seed	1412-1458	8	11	3.0	5.0	.4	15	120
4-14-77	1515-1735	4	Seed	1522-1706	9	12	3.0	5.0	2.0	25	320
4-14-77	1950-2040	5	Seed	2020-2020	10	10	4.5	4.5	Turb	---	20
4-16-77	1330-1505	6	Seed	1400-1437	-5	10	Ic	11.0	.2	1	140
4-18-77	1540-1620	7	Recon	---	11	11	6.0	6.0	---	---	-0-
4-18-77	1845-1940	8	Seed	1900-1906	16	17	5.8	5.8	1.0	3	20
4-20-77	1609-1855	9	Seed	1629-1830	8	12	5.0	6.0	2.0	20	440
4-28-77	1842-1957	10	Seed	1900-1934	11	17	5.0	7.0	1.8	12	140

Table 3-Continued

1 APRIL - SEPT. 30, 1977 CRMWD OBSERVED CLOUD SEEDING DATA

DATE	TIME (LDT)	FLT.#	MISSION	SEED TIME	CLOUD BASE TEMP. (°C) Min.	CLOUD BASE TEMP. (°C) Max.	CLOUD BASE HT. (K FT.) Min.	CLOUD BASE HT. (K FT.) Max.	MAXIMUM UPDRAFT Ft/Min	HORIZONTAL EXTENT N. Mi.	AgI DISPENSED (gm)
4-29-77	2204-2400	11	Seed	2215-2341	11	14	3.5	4.4	.6	5	160
5-4-77	1535-1620	12	Recon	---	15	15	7.0	7.0	---	---	-0-
5-5-77	1120-1150	13	Recon	---	18	18	6.5	6.5	---	---	-0-
5-5-77	1532-1900	14	Seed	1545-1745	13	16	5.5	6.0	2.2	38	400
5-8-77	2140-0105	15	Seed	2225-2442	17	18	3.0	4.5	.8	15	480
5-9-77	2026-2225	16	Seed	2034-2210	12	18	4.5	6.5	1.8	15	360
5-14-77	1910-2100	17	Seed	1920-2025	12	13	6.0	6.0	1.0	8	260
5-16-77	1405-1440	18	Recon	---	18	18	5.0	5.0	---	---	-0-
5-16-77	1725-1835	19	Seed	1812-1812	9	15	7.0	9.0	.8	3	60
5-18-77	1647-1745	20	Recon	---	16	16	7.0	7.0	---	---	-0-

Table 3-Continued

1 APRIL - SEPT. 30, 1977 CRMWD OBSERVED CLOUD SEEDING DATA

DATE	TIME (LDT)	FLT.#	MISSION	SEED TIME	CLOUD BASE TEMP. (°C) Min.	CLOUD BASE TEMP. (°C) Max.	CLOUD BASE HT. (K FT.) Min.	CLOUD BASE HT. (K FT.) Max.	MAXIMUM UPDRAFT Ft/Min	HORIZONTAL EXTENT N. Mi.	AgI DISPENSED (gm)
5-19-77	1530-1705	21	Seed	1600-1637	6	18	6.0	10.	.8	8	140
5-20-77	1820-2130	22	Seed	1830-2107	9	16	4.2	8.0	2.0	10	480
5-20-77	1506-1800	23	Seed	1520-1741	13	19	3.5	6.5	1.5	11	460
5-29-77	1950-2120	24	Seed	2017-2034	11	13	10	10	1.0	4	80
5-30-77	1905-2010	25	Seed	1920-2000	10	10	10	10	8	5	180
6-10-77	2058-2135	26	Recon	---	13	13	8.7	8.7	---	---	-0-
6-11-77	2003-2150	27	Seed	2025-2138	12	15	7.3	8.0	2.0	15	400
6-13-77	2230-2410	28	Recon	---	13	15	6.5	6.5	---	---	-0-
6-20-77	2230-2354	29	Seed	2245-2336	14	14	7.0	7.0	2.0	30	340
6-21-77	1205-1255	30	Recon	---	19	19	4.0	4.0	---	---	-0-

Table 3-Continued

1 APRIL - SEPT. 30, 1977 CRMWD OBSERVED CLOUD SEEDING DATA

DATE	TIME (LDT)	FLT.#	MISSION	SEED TIME	CLOUD BASE TEMP. (°C) Min.	CLOUD BASE TEMP. (°C) Max.	CLOUD BASE HT. (K FT.) Min.	CLOUD BASE HT. (K FT.) Max.	MAXIMUM UPDRAFT Ft/Min	HORIZONTAL EXTENT N. Mi.	AgI DISPENSED (gm)
6-21-77	1720-1845	31	Seed	1745-1817	4	5	11.5	11.5	1.0	2	140
6-22-77	1650-1810	32	Seed	1703-1806	18	20	3.0	4.5	1.0	15	240
6-23-77	1425-1545	33	Seed	1435-1537	17	21	3.5	5.2	1.0	15	220
6-23-77	1553-1625	34	Recon	---	9	9	---	---	---	---	-0-
6-24-77	2050-2247	35	Seed	2105-2237	17	20	4.0	6.0	1.2	15	480
6-25-77	945-1115	36	Seed	1015-1020	3	3	12.0	12.0	.3	1	20
6-25-77	1500-1730	37	Seed	1515-1717	16	16	5.0	7.0	2.0	10	400
6-25-77	1745-2001	38	Seed	1804-1943	16	19	5.5	7.0	1.0	10	380
6-25-77	2015-2145	39	Seed	2054-2125	14	18	6.0	7.5	.6	6	140
7-8-77	1250-1507	40	Seed	1300-1438	13	23	3.5	6.7	2.5	20	480

Table 3-Continued

1 APRIL - SEPT. 30, 1977 CRMWD OBSERVED CLOUD SEEDING DATA

DATE	TIME (LDT)	FLT.#	MISSION	SEED TIME	CLOUD BASE TEMP. (°C)		CLOUD BASE HT. (K FT.)		MAXIMUM UPDRAFT Ft/Min	HORIZONTAL EXTENT N. Mi.	AgI DISPENSED (gm)
					Min.	Max.	Min.	Max.			
7-9-77	1640-1730	41	Recon	---	16	16	7.0	7.0	---	---	-0-
7-21-77	1340-1600	42	Seed	1403-1540	15	19	5.5	7.0	2.0	10	400
7-21-77	1700-1747	43	Recon	---	18	18	5.0	5.0	---	---	-0-
7-27-77	1600-1755	44	Seed	1700-1725	7	7	11.0	11.5	1.0	2	140
7-28-77	1400-1620	45	Seed	1420-1604	14	18	7.0	8.0	1.0	10	180
7-29-77	1415-1600	46	Recon	---	16	17	7.0	7.5	---	---	-0-
8-11-77	1240-1320	47	Seed	1305-1310	15	15	7.0	7.0	.3	5	40
8-11-77	1415-1511	48	Seed	1435-1452	16	16	7.0	7.0	4	4	160
8-12-77	2000-2059	49	Seed	2025-2047	11	14	7.0	8.0	.3	3	80
8-13-77	1620-1655	50	Recon	---	12	12	9.0	9.0	---	---	-0-

Table 3-Continued

1 APRIL - SEPT. 30, 1977 CRMWD OBSERVED CLOUD SEEDING DATA

DATE	TIME (LDT)	FLT.#	MISSION	SEED TIME	CLOUD BASE TEMP. (°C) Min.	CLOUD BASE TEMP. (°C) Max.	CLOUD BASE HT. (K FT.) Min.	CLOUD BASE HT. (K FT.) Max.	MAXIMUM UPDRAFT Ft/Min	HORIZONTAL EXTENT N. Mi.	AgI DISPENSED (gm)
8-14-77	1535-1617	51	Seed	1545-1600	16	16	7.0	7.0	1.0	5	80
8-22-77	945-1030	52	Recon	---	10	10	10.5	10.5	---	---	-0-
8-23-77	1645-1800	53	Seed	1700-1724	8	12	10.5	11.5	1.3	3	60
8-23-77	1810-1900	54	Seed	1820-1843	9	20	10	11.0	.5	7	160
8-27-77	1728-1825	55	Seed	1749-1808	14	17	8.0	9.0	1.2	5	100
8-27-77	1840-2025	56	Seed	1856-2008	15	23	3.8	8.0	2.0	10	380
8-28-77	1515-1645	57	Seed	1542-1645	20	21	4.0	4.5	.6	10	480
8-28-77	1706-1745	58	Recon	---	19	19	5.0	5.0	---	---	-0-
9-17-77	1800-1842	59	Recon	---	11	11	9.0	9.0	---	---	-0-

project area during 1977:

Recording Gages	
Belfort	69
Fischer-Porter	9
MRI Tipping Bucket	2
Non-Recording Gages	
CRMWD Fence-Post	150
TOTAL	230

RAWINSONDE OPERATIONS

A District technician operated the RD-65 rawinsonde unit at Howard County Airport throughout the 1977 program. Data obtained were made available to Texas A&M University for use in the Texas-HIPLEX mesoscale analysis program and were also used by the District's radar meteorologist and the Department's resident forecaster for identifying those days when weather conditions warranted cloud-seeding operations.

The greatest number of rawinsondes launched in support of the Texas-HIPLEX field program occurred in June--the first 30 days of the field program (Table 4). The data collected by the RD-65 unit were assigned 7-digit codes for use in computer analyses (Table 5).

TABLE 4

MONTHLY SUMMARY OF RAWINSONDES

LAUNCHED AT BIG SPRING, TEXAS - 1977

	HIPLEX Program	CRMWD Program	Total
April	-0-	20	20
May	-0-	27	27
June	59	13	72
July	20	20	40
August	-0-	23	23
September	-0-	15	15
TOTAL	79	118	197

TABLE 5

RAWINSONDE LAUNCHES MADE AT BIG SPRING, TEXAS

FROM 1 APRIL - 30 SEPTEMBER 1977

Date	Local Time	Code	Date	Local Time	Code
08-04-77	0900	BG7A08P	24-05-77	0900	BG7524Ø
11-04-77	0900	BG7A11P	25-05-77	0900	BG7525Ø
12-04-77	0900	BG7A12P	26-05-77	0900	BG7526Ø
12-04-77	1400	BG7A12U	31-05-77	0900	BG7531Ø
13-04-77	0900	BG7A13P	01-06-77	1000	BG7601P*
14-04-77	0900	BG7A14P	01-06-77	1300	BG7601S*
14-04-77	1500	BG7A14V	01-06-77	1600	BG7601V*
15-04-77	0900	BG7A15P	01-06-77	1900	BG7602A*
18-04-77	0900	BG7A18P	01-06-77	2200	BG7602D*
18-04-77	1800	BG7A19A	02-06-77	1000	BG7602P
19-04-77	0900	BG7A19P	03-06-77	0900	BG7603Ø
20-04-77	0900	BG7A20P	06-06-77	0900	BG7606Ø
21-04-77	0900	BG7A21P	07-06-77	1000	BG7607P*
22-04-77	0900	BG7A22P	07-06-77	1300	BG7607S*
25-04-77	1900	BG7A26A	07-06-77	1600	BG7607V*
26-04-77	1000	BG7A26P	07-06-77	1900	BG7608A*
27-04-77	0900	BG7A27Ø	07-06-77	2200	BG7608D*
28-04-77	0900	BG7A28Ø	08-06-77	0900	BG7608Ø
28-04-77	1700	BG7A28W	09-06-77	1000	BG7609P*
29-04-77	1200	BG7A29R	09-06-77	1300	BG7609S*
02-05-77	0900	BG7502Ø	09-06-77	1600	BG7609V*
03-05-77	0900	BG7503Ø	09-06-77	1900	BG7610A*
04-05-77	0900	BG7504Ø	09-06-77	2200	BG7610D*
05-05-77	0900	BG7505Ø	10-06-77	0900	BG7610Ø
05-05-77	0900	BG7506Ø	11-06-77	1000	BG7611P*
09-05-77	0900	BG7509Ø	11-06-77	1300	BG7611S*
10-05-77	0900	BG7510Ø	11-06-77	1600	BG7611V*
11-05-77	0900	BG7511Ø	11-06-77	1900	BG7612A*
12-05-77	0900	BG7512Ø	11-06-77	2200	BG7612D*
13-05-77	0900	BG7513Ø	13-06-77	1000	BG7613P*
14-05-77	0900	BG7514Ø	13-06-77	1300	BG7613S*
16-05-77	0900	BG7516Ø	13-06-77	1600	BG7613V*
17-05-77	0900	BG7517Ø	13-06-77	1900	BG7614A*
18-05-77	1100	BG7518Q	13-06-77	2200	BG7614D*
18-05-77	1300	BG7518S	14-06-77	0900	BG7614Ø
18-05-77	1500	BG7518U	15-06-77	0900	BG7615Ø
18-05-77	1700	BG7518W	16-06-77	0900	BG7616Ø
18-05-77	1900	BG7519A	17-06-77	0900	BG7617Ø
19-05-77	0900	BG7519Q	20-06-77	0900	BG7620Ø
20-05-77	1100	BG7520Q	21-06-77	1000	BG7621P*
20-05-77	1300	BG7520S	21-06-77	1300	BG7621S*
20-05-77	1500	BG7520U	21-06-77	1600	BG7621V*
20-05-77	1900	BG7521R	21-06-77	1900	BG7622A*

*Mesoscale Rawinsonde

TABLE 5 (Cont'd)

Date	Local Time	Code	Date	Local Time	Code
21-06-77	2200	BG7622D*	09-07-77	2200	BG7709D*
22-06-77	1000	BG7622P*	09-07-77	1000	BG7709P*
22-06-77	1300	BG7622S*	09-07-77	1300	BG7709S*
22-06-77	1600	BG7622V*	09-07-77	1600	BG7709V*
22-06-77	1900	BG7623A*	09-07-77	1900	BG7710A*
22-06-77	2200	BG7623D*	10-07-77	2200	BG7710D*
23-06-77	1000	BG7623P*	10-07-77	1000	BG7710P*
23-06-77	1300	BG7623S*	10-07-77	1300	BG7710S*
23-06-77	1600	BG7623V*	10-07-77	1600	BG7710V*
23-06-77	1900	BG7624A*	10-07-77	1900	BG7711A*
23-06-77	2200	BG7624D*	11-07-77	2200	BG7711D*
24-06-77	1000	BG7624P*	11-07-77	0900	BG7711Ø
24-06-77	1300	BG7624S*	12-07-77	0900	BG7712Ø
24-06-77	1900	BG7624V*	13-07-77	1000	BG7713P
24-06-77	1900	BG7625A*	14-07-77	0900	BG7714Ø
24-06-77	2200	BG7625D*	15-07-77	0900	BG7715Ø
25-06-77	1000	BG7625P*	19-07-77	0900	BG7719Ø
25-06-77	1300	BG7625S*	20-07-77	0900	BG7720Ø
25-06-77	1600	BG7625V*	21-07-77	0900	BG7721Ø
25-06-77	1900	BG7626A*	22-07-77	0900	BG7722Ø
25-06-77	2200	BG7626D*	25-07-77	0900	BG7725Ø
27-06-77	1000	BG7627P*	26-07-77	0900	BG7726Ø
27-06-77	1300	BG7627S*	27-07-77	0900	BG7727Ø
27-06-77	1600	BG7627V*	28-07-77	0900	BG7728Ø
27-06-77	1900	BG7628A*	28-07-77	1200	BG7728R
27-06-77	2200	BG7628D*	28-07-77	1500	BG7728U
28-06-77	0900	BG7628Ø	28-07-77	1800	BG7728X
29-06-77	0900	BG7629Ø	29-07-77	0900	BG7729Ø
30-06-77	0900	BG7630Ø	02-08-77	0900	BG7802Ø
30-06-77	1300	BG7630S*	03-08-77	0900	BG7803Ø
30-06-77	1600	BG7630V*	04-08-77	0900	BG7804Ø
30-06-77	1900	BG7701A*	05-08-77	0900	BG7805Ø
30-06-77	2200	BG7701D*	08-08-77	0900	BG7808Ø
01-07-77	1200	BG7701R	09-08-77	0900	BG7809Ø
05-07-77	0900	BG7705Ø	10-08-77	0900	BG7810Ø
06-07-77	0900	BG7706Ø	11-08-77	0900	BG7811Ø
07-07-77	1000	BG7707P*	12-08-77	1200	BG7812R
07-07-77	1300	BG7707S*	15-08-77	0900	BG7815Ø
07-07-77	1600	BG7707V*	16-08-77	0900	BG7816Ø
07-07-77	1900	BG7708A*	17-08-77	0900	BG7817Ø
08-07-77	2200	BG7708D*	19-08-77	0900	BG7819Ø
08-07-77	1000	BG7708P*	20-08-77	1200	BG7820R
08-07-77	1300	BG7708S*	21-08-77	0900	BG7821Ø
08-07-77	1600	BG7708V*	22-08-77	0900	BG7822Ø
09-07-77	1900	BG7709A*	23-08-77	0900	BG7823Ø

TABLE 5 (Cont'd)

Date	Local Time	Code	Date	Local Time	Code
24-08-77	0900	BG7824Ø			
25-08-77	0900	BG7825Ø			
26-08-77	0900	BG7826Ø			
29-08-77	0900	BG7829Ø			
30-08-77	0900	BG7830Ø			
31-08-77	0900	BG7831Ø			
01-09-77	0900	BG7901Ø			
06-09-77	0900	BG7906Ø			
07-09-77	0900	BG7907Ø			
08-09-77	0900	BG7908Ø			
12-09-77	0900	BG7912Ø			
13-09-77	0900	BG7913Ø			
14-09-77	0900	BG7914Ø			
15-09-77	0900	BG7915Ø			
16-09-77	0900	BG7916Ø			
19-09-77	0900	BG7919Ø			
20-09-77	0900	BG7920Ø			
21-09-77	0900	BG7921Ø			
22-09-77	0900	BG7922Ø			
23-09-77	0900	BG7923Ø			
28-09-77	0900	BG7928Ø			

BIG SPRING AIRCRAFT, INCORPORATED

"HIPLEX OBSERVATION AIRCRAFT PROGRAM"

LIST OF TABLES

Number	Title	Page
1	Summary of Missions Flown by the BSA Observation Aircraft during the 1977 Texas-HIPLEX Program	67

A Cherokee, instrumented aircraft was provided by Big Spring Aircraft, Inc., under contract with the Texas Water Development Board, in support of the field portion of the 1977 Texas-HIPLEX Program. The aircraft functioned as a cloud survey platform for gathering sub-cloud measurements of meteorological parameters such as wet and dry-bulb temperatures at cloud-base level as well as updraft profiles for a large sample of clouds. The BSA aircraft made a total of 19 flights during the 45-day field program, 6 of which resulted in the collection of cloud-base data (Table 1). A final report on the work of Big Spring

Table 1. Summary of Missions Flown by the BSA Observation Aircraft During the 1977 Texas HIPLEX Program.

Purpose	Number of Flights	Time (Hours)
Collecting cloud-base data	6	21.5
Aircraft radiosonde calibration	2	5.0
Transportation of equipment	3	2.5
"Dry run"	3	2.5
Photographs	1	1.0
Calibration of other equipment	1	3.3
Other	3	4.9
TOTAL	19	40.7

Aircraft, Inc. in support of the 1977 Texas-HIPLEX Program was submitted to the Bureau as an appendix to the July 1977 monthly progress report on the Texas-HIPLEX Program.

SECTION II

WORK PLANNED FOR THE PERIOD
OCTOBER 1, 1977 - MARCH 31, 1978

Management of the Texas-HIPLEX Program and Support Studies

Among the activities related to the Texas-HIPLEX Program which are planned for the next reporting period (October 1, 1977 - March 31, 1978) by the Department staff are:

Administration of the 1974 Agreement between the Bureau and the Department, including the negotiation and execution of contracts between the Department and organizations expected to participate in the 1978 Texas-HIPLEX Program; the work and services to be provided by the contracted institutions are described in "A Proposal for Work and Services in Support of the 1978 Texas-HIPLEX Program," which was submitted by the Department to the Bureau on September 29, 1977; funds to be used to support these various programs include the $100,000 appropriation by the 65th Texas Legislature for the Texas-HIPLEX Program and monies obligated to the Texas program during Fiscal Year 1978 by the Bureau;

Coordination with the Bureau in developing an operations plan for the field portion of the 1978 Program at Big Spring;

Sponsorship of and participation in meetings of the Texas-HIPLEX Advisory Committee;

Statistical analysis by the Department's Big Spring resident meteorologist of 1976-77 terminal forecast input data to derive an objective forecast "decision" tree (an outline of the analysis procedures to be followed is given as Appendix B);

Continuation of the development of the thunderstorm prediction model for use during the 1978 Texas-HIPLEX Field Program;

Conduct of an analysis of ice-nuclei data obtained during 1977 from observation points in Stanton, Big Spring, Colorado City, and Lubbock (an outline of the procedure to be followed in analyzing the data is given as Appendix C);

Publication of a Department technical report on all weather modification activities conducted in Texas during 1974-77, including descriptions of the 1975, 1976, and 1977 Texas-HIPLEX Programs, and a brochure describing and illustrating the various elements of the current Texas-HIPLEX Program;

Continuation of a Federal-State cost-sharing study of the economic effects of weather modification activities in the Big Spring-HIPLEX area, addressing in particular the effects of rainfall on the level of municipal and industrial water supplies and water use patterns and the recreational use of reservoirs in the study region; and

Probable relocation of the Department's Meteorological Facility from Howard County Airport to the installation near Big Spring formerly known as Webb Air Force Base.

Synder Radar Data Analysis

Now that a plan for analyzing radar data has been developed, efforts will be initiated to improve existing software for use in computer processing the data tapes. In general, this calls for an early conversion of the M-33 data into the Bureau's format, with a resultant reduction in processing time. The software improvements should require a period of about one month, at the end of which a test tape should be available. Approximately two more months will be needed to complete processing of the 1977 data tapes and data for about six 1976 operational days.

A program to analyze data for a mesoscale case study day will continue to be developed during the next 6-month reporting period. The selected case study day is June 22-23, 1976, for which certain analysis products appear in Section I of this report. The analysis will also include an examination of the synoptic scale environment, the propagation and dissipation of the squall line, and the 3-dimensional structure of the line.

It is expected that results of this analysis will have proceeded sufficiently in January such that useful discussions can be begun with other participants in the Texas-HIPLEX Program.

Mesoscale Data Analysis

The following tasks are due to be completed during the reporting period of October 1, 1977 - March 31, 1978:

1. A data report containing the surface and upper-

atmospheric weather data for the summer of 1977 will be prepared in the same format as the 1976 report.

2. The sounding data will be provided to the Bureau of Reclamation on magnetic tape in a format suitable for use by their computer.
3. A trip will be made to the Bureau offices in Denver to assist with processing of the soundings data collected during the summer of 1977.
4. Analysis of the data collected during the summer of 1976 will continue, with a detailed report to be prepared by December 1977 or January 1978.
5. Analysis of the 1977 data will commence.

Radar-Echo Climatology for the Southern HIPLEX Region

Computer card punching will begin and programs will be written to extract the needed radar-echo characteristics. The original estimate of eleven months required to complete the program is still valid. The program should be completed by May 15, 1978. A more detailed timetable is as follows:

Computer card punching	October 1 - December 1, 1977
Program writing	October 1 - December 1, 1977
Computer runs	December 1 - December 20, 1977
Climatological analysis	January 1 - February 1, 1978
Synoptic analysis	February 1 - April 1, 1978
Writeup	April 1 - May 15, 1978

Satellite-Derived Cloud Climatology for the Southern HIPLEX Region

During the next reporting period, a review of 1976 and 1977 satellite radiance data to determine cloud characteristics during the summer in the Texas-HIPLEX operational site will be continued. A region of 90,000 km^2 centered at Big Spring, Texas will be examined in this phase of the program. The cloud parameters of interest will be initial time and location of development, growth rate vertically and horizontally, direction and rate of propagation, and relation of cloud properties to meso-synoptic features. Cloud conditions will be summarized at different times of the day to monitor diurnal variations as well.

In addition, results from the study of visible and infrared photographic data will be compared to those obtained from the examination of radiance data.

Precipitation Climatology for the Southern HIPLEX Region

Research in the area of development of a precipitation climatology for the Southern- HIPLEX Region during the period October 1 - December 31, 1977 will center on meso-synoptic events producing rainfall of various types and amounts within the Texas-HIPLEX rain-gage network. Daily and hourly rainfall data collected by this network will be utilized in this aspect of the overall investigation, which is to be concluded by December 31, 1977.

HIPLEX Rain-Gage and Rawinsonde Support Programs

District personnel will be conducting an evaluation of rainfall, crop yield, and other data which were collected during the District's 1977 cloud-seeding program. The evaluation will be similar to that made in 1975 and 1976 using data collected during those two years. The analyses will examine data for both the District's cloud-seeding target area and for areas adjacent to it.

In addition, contingent upon the approval of the Bureau and the Department, District personnel will begin the construction and placement within the Texas HIPLEX project site of support, post-type bases for the Texas-HIPLEX rain-gage network. Plans also call for upgrading radio communications among the District's radar facilities, the District's cloud-seeding aircraft, and the observation aircraft to be used in 1978.

The District's rawinsonde technician will be performing during the next six months analyses of rawinsonde data collected at Big Spring and from the meso-network of rawinsonde stations maintained by Texas A&M University.

SECTION III

PERSONNEL

Management of the Texas-HIPLEX Program and Support Studies (TDWR)

John T. Carr, Jr.	Director, TDWR Weather Modification & Technology Division
Robert Riggio	Meteorologist
George Bomar	Meteorologist
William Alexander	Resident Forecaster at Big Spring
Thomas Larkin	Meteorologist
William Hanshaw	Rain-Gage Technician
Keith Topham	Computer Program Analyst
Mike Olivares	Computer Programmer
Mike Kengla	Economist

Snyder Radar-Data-Collection Program and Data Analysis (MRI)

T. B. Smith	Supervisor
Don Takeuchi	Principal Investigator
Robert Anderson	Project Manager at Snyder
Robert Schaff	Radar Technician
Dean House	Radar Technician
Ed Huber	Radar Technician

Mesoscale Field Program and Data Analysis (TAMU)

James R. Scoggins	Principal Investigator, Director of Project
James E. Arnold	Instrumentation and Planning
Gregory S. Wilson	Computer Programmer and Analyst
Mark E. Humbert	TAMU Field Program Manager, Data Specialist, and Analyst
Gordon Grant	Data Specialist
John Rod	Data Specialist
Pete Reynolds	Rawinsonde Operator, Data Specialist, and Analyst
Jack Hinson	Rawinsonde Operator and Data Specialist
Steven Bishkin	Rawinsonde Operator and Data Specialist
Terry Allison	Electronics Technician, Rawinsonde Operator, and Data Specialist
Myron Gerhard	Data Specialist
Henry E. Fuelberg	Analyst
Jackie Wilson	Keypunch Operator
Doreen Westwood	Data Specialist and Draftsman
Karen Cobbs	Typist, Keypunch Operator, and Data Specialist

Radar-Echo Climatology for the Southern HIPLEX Region (TAMU)

Dennis M. Driscoll	Principal Investigator, Director of Project
Judson W. Ladd	Graduate Research Assistant, Supervisor of Personnel and Project Activities
Craig Z. Lowery	Technician (April 20-31; July 6-August 19)
William D. Nichols	Technician (June 10-August 23)
Mac Pitchford	Technician (May 20- July 27)
Frank D. Mazuvowski	Technician (July 26-August 22)

Satellite-Derived Cloud Climatology for the Southern HIPLEX Region (TTU)

Gerald M. Jurica	Principal Investigator, Director of Project
Vicki Thrasher	Research Associate, Processing of Digital Tapes
Schwe-Yi Chi	Graduate Research Assistant, Cloud Characteristic Study
Shih Cheng Chae	Graduate Research Assistant, Analysis of Radiance Data
Russell Pfost	Graduate Research Assistant, Acquisition and Analysis of Satellite Imagery
Gary Osborn	Student Assistant, Computer Programming
Debrajean Kerr	Secretary, Documentation and Reporting

Precipitation Climatology for the Southern HIPLEX Region (TTU)

Donald R. Haragan	Principal Investigator, Director of Project
Joe Falkner	Research Assistant
Libby Patterson	Keypunch Operator
Hames Holman	Student Assistant, Computer Programming

HIPLEX Rain-Gage and Rawinsonde Support Programs (CRMWD)

Owen H. Ivie	General Manager, Colorado River Municipal Water District

HIPLEX Rain-Gage and Rawinsonde Support Programs (CRMWD)(Cont'd)

R. A. Schooling	Coordinator and Supervisor
John Girdzus	Radar Meteorologist
Alan Giacomelli	Cloud-Seeding Aircraft Pilot
Harold Hancock	Rawinsonde Technician
Humberto Padillo	Raing-Gage Technician

HIPLEX Observation Aircraft Support (BSA)

John Whitmire	President, Big Spring Aircraft, Incorporated
Leon Anderson	Aircraft Pilot

APPENDIX A

AN ANALYSIS OF FORECASTS ISSUED IN SUPPORT OF THE 1977 TEXAS-HIPLEX PROGRAM

The 1977 Texas-HIPLEX Field Program marked the second year during which the Texas Department of Water Resources has provided an on-site forecasting meteorologist in support of Program activities at Big Spring. The forecaster operated from the Department's Meteorological Facility located at Howard County Airport near Big Spring, and routinely provided detailed forecasts for the various Texas-HIPLEX Program participants.

The performance of the forecaster is crucial, since the operational status of the various elements of the extensive program is dependent upon the nature of his forecasts. It is essential that improvements be made continually in forecast precision and accuracy. The following is an evaluation of that forecasting performance. The reader should note that the analysis of forecast accuracy is not free of bias, since forecast verification was accomplished with the use of the resident meteorologist's own observations, rather than some independent observations such as surface and radar weather reports made by U.S. Air Force personnel at Webb AFB.

Procedure

Due to the nature of HIPLEX, the HIPLEX forecaster must provide a much more detailed forecast than that provided by the National Weather Service. This requires that he have access to additional and more detailed data with which to formulate his forecasts. Therefore, in addition to the NAFAX facsimile and synoptic data received from the National Meteorological Center and hourly

FAA and NWS surface observations via teletype circuitry, other data sources unique to HIPLEX are available in-house. The U. S. Bureau of Reclamation's Division of Atmospheric Water Resources Management has developed the Environmental Data Network (EDN), a set of meteorological programs designed to produce superior fine mesh data (both real time and prognostic). These data are produced through the Bureau's CYBER 74 computer located in Denver, Colorado and are accessed via data terminals located at the weather facility at Howard County Airport (as well as at the two other HIPLEX sites in Kansas and Montana). These EDN programs are capable of interpolating and extrapolating from NWS surface and upper air data to produce fine mesh gridded field data vital to the needs of the forecaster.

Additionally, the forecaster is provided with rawinsonde data derived from daily balloon launchings at Howard County Airport. This provides data otherwise unavailable, since the nearest NWS rawinsonde launch site is at Midland Air Terminal--forty miles away. This allows for finer detail in upper air analysis and often reveals sub-synoptic/mesoscale perturbations critical to the forecast.

The forecast itself is designed to provide participating research organizations with various meteorological data. The forecast provides a brief synopsis of the morning's regional weather features, as well as a prognostication of these features valid for the forecast period. Surface temperatures and winds are forecasted, as well as the anticipated upper air temperatures and winds at 850, 700, and 500 mb. Moisture amounts, stability, and anticipated precipitation types are provided in addition to cloud depth, height, and temperature information. The forecast is designed to provide suitable information to prepare for a detailed examination of the atmosphere.

There are three basic forecasts prepared daily during the Texas HIPLEX period. First, at 1130 local time, a twelve hour forecast, valid from 1300 through dark local time, is issued. The 1130 forecast is the primary HIPLEX forecast, and operations are based on the data provided therein. Second, at 1630 local time, a six hour update, valid from 1700 to dark, is issued. This forecast may revise the 1130 forecast, and operations may either continue or terminate for the day based on this forecast. Finally, also at 1630, the next-day outlook (twenty-four hour), valid from 1300 until dark, is issued. Based on the next-day outlook are the proposed radar and rawinsonde operations, as well as any possible "standdown" days (days off).

Performance

An operational day, as defined at the Third HIPLEX Technecical Conference*, is any day during the HIPLEX season in which

*27-29 September,1976; Denver, Colorado

convective clouds develop which have a minimum vertical depth of 7000', whose bases are $\leq$12000' AGL, and whose cloud top temperature $\geq$-5°C. A non-operational day is one in which either the above criteria are not met or the potential exists for severe weather over or adjacent to the operational area during the forecast period.

These criteria may be verified in several ways. First and most importantly are surface observations from Howard County Airport. From the airport, convective cells meeting HIPLEX criteria may be seen visually over most of the operational area, except on days when visibility is reduced. Most of forecast verification is based on the HCA surface obersvations. Secondly, radar observations from HCA support the surface observations. If visibility is reduced at the station, the radar unit serves to detect from very light rainshowers up through heavy thunderstorms. Thirdly, pilot reports from HIPLEX aircraft are examined post-operation for cloud base height and temperature information. This aids in determination of fulfillment of HIPLEX criteria. With these data forecasts are examined for accuracy.

These forecasts are compiled during the season and retained for post analysis. The forecasts have been stratified below, with update forecasts deleted because of their short-term nature.

	May	June	July	August	Sept	Overall
# Forecasts	31	30	31	29	27	148
hit	24	28	29	24	25	130
missed	7	2	2	5	2	18
%	77.4	93.3	93.5	82.8	92.6	87.8

FIGURE I: 12-hour forecast performance for 1977

Similarly, the twenty-four hour forecasts have been tabulated. These were issued during June and July of 1977 and were used during meso-scale operations:

	June	July	Overall
# Forecasts	24	10	34
hit	17	8	25
missed	7	2	9
%	70.8	80.0	73.4

FIGURE II: Twenty-four hour forecast performance for 1977

Additionally, these figures may be compared to standard measurementsof forecasting ability. The first measurement is the persistence forecast. The persistence forecast is derived from the philosophy that whatever occurs on any given day will occur the following day. This is a good indicator, when compared to the actual forecast, of how much skill is required to achieve the forecaster's verification percentage. If, for example, persistence was able to forecast correctly eighty percent of the days, the forecaster--if skilled--will do significantly better than that. In this light, let us examine the persistence data:

	May	June	July	August	Sept.	Overall
# Forecasts (Persistence)	31	30	31	28	25	145
hit	17	21	24	20	20	102
miss	14	9	7	8	5	43
%	54.8	70.0	77.4	71.4	80.0	70.3

FIGURE III: Twelve hour persistence forecasts for 1977

	June	July	Overall
# Forecasts (Persistence)	20	6	26
hit	17	5	22
missed	3	1	4
%	85.0	83.3	84.6

FIGURE IV: Twenty-four hour persistence forecasts for 1977

Another forecast measurement tool is that of forecasting precipitation 100% of the time. In an area of frequent precipitation, this comparison works similarly to persistence, in that the forecaster should--if skilled--be able to filter those few days in which precipitation will not occur. However, the 1977 Texas HIPLEX figures listed below indicate an interesting point:

	May	June	July	August	Sept.	Overall
# Forecasts (100% prec.)	31	30	31	29	27	148
hit	16	13	7	15	7	58
missed	15	17	24	14	20	90
%	51.6	43.3	22.6	51.7	25.9	39.2

FIGURE V: Twelve hour 100% precipitation forecasts for 1977

	June	July	Overall
# Forecasts (100% prec.)	24	10	34
hit	10	2	12
missed	14	8	22
%	41.7	20.0	35.3

FIGURE VI: Twenty-four hour 100% precipitation forecasts for 1977

Clearly, if one were to expect precipitation on a daily basis in the Texas HIPLEX operational area, he would be sorely mistaken. Only 39.2% of the forecast days were precipitation days in 1977.

Thusfar we have been examining only 1977 forecast data. In order to bring this study into proper perspective, let us now review the 1976 season. During 1976, active forecasting was tabulated based on data between 11 May and 30 September, for a total of 134 forecast days. This was the initial Texas HIPLEX forecasting season. A summary of the twelve and twenty-four hour forecast performance:

	May	June	July	August	Sept.	Overall
# Forecasts	19	25	30	31	29	134
hit	15	22	26	25	24	112
missed	4	3	4	6	5	22
%	78.9	88.0	86.7	80.6	82.8	83.6
# op days	10	14	25	14	20	83
# non-op days	9	11	5	17	9	51
% op days	52.6	56.0	83.3	45.2	69.0	61.9
# persist. fcsts.	17	24	29	31	28	129
persist. hit	12	16	22	24	21	95
persist. missed	5	8	7	7	7	34
% persist. hit	70.6	66.7	75.9	77.4	75.0	73.6

FIGURE VII: Twelve hour forecast summary for 1976

	June	July	Overall
# Forecasts	15	22	37
hit	10	17	27
missed	5	5	10
%	66.7	77.3	73.0
# op days	6	16	22
# non-op days	8	6	14
% op days	46.7	72.7	62.2
# persist. fcsts.	15	22	37
persist. hit	11	16	27
persist. missed	4	6	10
% persist. hit	73.3	72.7	73.0

FIGURE VIII: Twenty-four hour forecast summary for 1976

Overall, the twelve hour forecasts improved from 1976 to 1977. In fact, the 1976 percentage correct for forecasting precipitation was 83.6, while in 1977 the figure was 87.8, an increase of 4.2%. This is particularly notable, since persistence forecasts actually decreased from 73.6 to 70.3%, a 3.3% drop. However, with twenty-four hour forecasts only marginal improvement occurred. In 1976 the overall hit percentage was 73.0, while the 1977 percentage was 73.4. The futility of the twenty-four hour forecasts is obvious, however, as persistence matched the forecaster's performance in 1976 with 73.0%, while embarrassingly it bettered the forecaster in 1977 with strong 84.6% showing.

The forecast efficiency peaked both years during the most important portion of the forecasting season: June and July (the HIPLEX months). 1976 was forecasted correctly 88.0% for June and 86.7% for July, while 1977 had an excellent 93.3% in June and an even better 93.5% in July. Performances were poorest both early and late in each season. May of 1976 had 78.9% correct, while May of 1977 dipped to 77.4%. September of 1976 was 82.8% and August of 1977 was only 82.8%. The only exception to this trend was September of 1977, when 92.6% of the forecasts were correct. Notice, however, that persistence scored a healthy 80.0% during this month.

The 1977 season was the considerably drier, with only 39.2% of the forecast days being operational. In contrast, a whopping 61.9% of the 1976 forecast days were operational. The significance of this statistic comes into focus through examination of forecast performance on operational and non-operational days:

	1977	1976	Overall
# Forecast days	148	134	282
op days	58	83	141
hit	49	67	116
missed	9	16	25
% hit	84.5	80.7	82.3
non-op days	90	51	141
hit	81	45	126
missed	9	6	15
% hit	90.0	88.2	89.4

FIGURE IX: Forecast performance on operational, non-operational days in 1976 and 1977

The non-operational day forecasting was clearly superior both years. Obviously, it would seem that a non-operational day is more clearly recognizable than an operational day. This chart also displays where the greatest amount of improvement showed up in 1977--operational day forecasting. The 1977 operational day forecasts were nearly four percent better than their 1976 counterparts.

Summary

1977 was a good year for forecasting at the Texas HIPLEX. The verification percentages indicate improvement in every phase of the forecasting operation. The accumulation of well-organized and easily stratified data is a great asset in the development of statistical analyses. In 1977 this was accomplished quite well with on-site rawinsondes, surface and radar observations, the recording and archiving of climatological data, and the on-site computer storage and programming capability of the Bureau of Reclamation's CYBER-74 interact data terminal system.

Of particular note was the fact that, as in 1976, forecast accuracy peaked during the HIPLEX mesoscale months of June and July. This allowed for a high confidence factor with HIPLEX participants. Due in part to this fact, considerable representative data was accumulated during the Texas A&M University mesoscale portion of HIPLEX, and the Meteorology Research, Inc. digital radar study.

Conclusions

Forecasting for the Texas HIPLEX improved during 1977. The twelve hour forecasts were the more improved of the two. In the face of persistence, which decreased in verification percentage for 1977, the forecasts improved significantly. Here, it must be noted that the forecast improvement should not be attributed to the abundance of non-operational (easier to forecast) days in 1977. The non-operational day forecasts improved, although marginally. The largest improvement was in forecasting operational days. The availability by forecast time of the 1977 Big Spring morning rawinsonde data has been the one additional input for 1977, and has supplied the forecaster's needs for detailed sub-synoptic scale upper air information. This was not available by forecast time in 1976, and seems to have been the area of improvement.

Further development of forecasting methods are in process at this time. A statistical analysis of all input data is currently being made, and the results thereof will be the foundation for a logical, objective forecast decision tree. Employing the 1976 and 1977 input data to provide guidance for future forecasting will, hopefully, improve forecasting ability--particularly at the twenty-four hour level. The results of this analysis are eagerly awaited, as are future HIPLEX seasons.

APPENDIX B

OUTLINE OF STUDIES TO BE MADE ON

1977 TEXAS-HIPLEX FORECAST DATA

I. Stratification of 1976-1977 Forecast Days, According to the Modified Hartzell Stratification Class Characterization

II. Examination of Forecasts of Maximum Temperatures

- A. Method of obtaining maximum temperature forecasts.
- B. Significance of maximum temperature forecasts.
- C. Accuracy of maximum temperature forecasts.

III. Examination of input parameters vs. convective intensity (I)

- A. Total temperature (T500mb+T700mb+T850mb) (C)
- B. Precipitable water (surface-500 mb) (cm.)
- C. Stability Indices
  1. Total totals
  2. Lifted
  3. K
  4. Sweat
  5. "Total stability"
- D. Existence of mechanical/dynamic trigger mechanisms
- E. Barotropic 12-hour vorticity advection
- F. Observed maximum and convective temperatures

IV. Graphical Analyses (III.A. by III.B)

- A. Stratification classes 1 through 9
- B. Vorticity advection (less than |1.0|)
- C. Vorticity advection (equal to 1 greather than |1.0|)

V. Incorporation of above data into decision tree

CLASSIFICATION OF CONVECTIVE INTENSITY

(Modified for West Texas HIPLEX Operational Area from Hartzell, 1976)

CLASS NUMBER	DEFINITION
1	Clear or cirrus and non-precipitating mid-level altocumulus or altostratus
2	Mid-level clouds with virga or RW-; no low level clouds
3	Non-precipitating convective clouds (i.e., stratocumulus to small cumulus congestus)
4	Towering cumulus with virga but no rain reaching ground
5	Towering cumulus with light rainshowers which developed within the operational area either randomly or in lines; no cumulonimbus observed
6	Similar to 5 with cumulonimbus and thunderstorms which developed within operational area in addition to towering cumulus
7	Mesoscale cumulonimbus system which developed W-SW of operational area due upslope and/or dry line-sfc trough and moved across operational area as line of thunderstorms or rainshowers
8	Meso-scale system developed along synoptic feature (i.e. cold front or short wave aloft) and moved across operational area as line of thunderstorms or rainshowers
9	Widespread precipitation from overcast nimbo-stratus

APPENDIX C

ANALYSIS OF THE 1977 TEXAS-HIPLEX MILIPORE DATA

I. INTRODUCTION AND BACKGROUND

II. DATA TO BE ANALYZED

A. Aerosal Counts

1. Stanton
2. Big Spring
3. Colorado City
4. Lubbock

B. Mean Wind Vectors

1. Midland
2. Abilene
3. San Angelo
4. Lubbock
5. Big Spring

C. Visibility

1. Midland
2. Abilene
3. San Angelo
4. Lubbock
5. Big Spring

D. Amounts of Silver Iodide Released

1. Colorado River Municipal Water District
2. Krick North Central Texas Project
3. Krick Trans-Pecos Texas Project
4. Better Weather, Inc. - Plains Weather Improvement Association, Hail

E. Stability Indices

1. Midland
2. Big Spring

F. Convective Intensity

1. Midland
2. Big Spring
3. Lubbock
4. Abilene
5. San Angelo

III. ANALYSES TO BE PERFORMED

A. Histogram (Mean, Median, Mode, Standard Division)

1. Aerosol counts
2. Mean wind vectors
3. visibility
4. Silver iodide released
5. Stability
6. Convective intensity

B. Linear Regression

1. Aerosol counts vs. mean wind vectors
2. Aerosol counts vs. visibility
3. Aerosol counts vs. silver iodide released
   a) Stanton/Trans-Pecos Texas Krick Site
   b) Big Spring/Colorado River Municipal Water District
   c) Colorado City/North Central Texas Krick Site
   d) Littlefield & Plainview/Better Weather, Inc. - Plains Weather Improvement Association hail suppression sites
4. Aerosol counts vs. stability
5. Aerosol counts vs. convective intensity
   a) Stanton/Midland
   b) Big Spring/Big Spring
   c) Lubbock/Lubbock
   d) Colorado City/ San Angelo, Abilene

C. Wind Field/Travectory Analyses

1. Surface winds over Midland, Big Spring, Lubbock, San Angelo, Abilene vs. same-day aerosol counts
2. Surface winds over Midland, Big Spring, Lubbock, San Angeolo, Abilene vs. next-day aerosol counts
3. Aerosol counts vs. next-day AgI counts for corresponding sites.

IV. SUMMARY

V. CONCLUSIONS