TEXAS HIPLEX
INTERIM PROGRESS REPORT

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Published April 10, 1980

Interim Progress Report for October 1, 1979–March 31, 1980

Prepared for:

OFFICE OF ATMOSPHERIC RESOURCES MANAGEMENT
WATER AND POWER RESOURCES SERVICE
BUILDING 67, DENVER FEDERAL CENTER
DENVER, COLORADO 80225

LP-128
May 1980

MS-230 (3-78)
Bureau of Reclamation

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.

4. TITLE AND SUBTITLE
Texas HIPLEX Interim Progress Report
October 1, 1979 - March 31, 1980

5. REPORT DATE
April 10, 1980

6. PERFORMING ORGANIZATION CODE
580/330

7. AUTHOR(S)
Staff, Weather Modification & Tech. Section
Planning & Development Division

8. PERFORMING ORGANIZATION REPORT NO.
LP-128

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Texas Department of Water Resources
P. O. Box 13087; Capitol Station
Austin, Texas 78711

10. WORK UNIT NO.
5540

11. CONTRACT OR GRANT NO.
14-06-D-7587

12. SPONSORING AGENCY NAME AND ADDRESS
Office of Atmospheric Resources Management
Water and Power Resources Service
Denver Federal Center; Box 25007
Denver, Colorado 80225

13. TYPE OF REPORT AND PERIOD COVERED
Interim

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This interim report represents a description of the continued evaluation of 1976-79 Texas HIPLEX data. Included are progress reports on mesoscale data evaluation, development of a radar-echo climatology, analysis of satellite, radar and precipitation gauge data, and the processing of 1976-78 Snyder, Texas M-33 digital radar data.

Emphasis is placed on the analysis of two prime case-study days, June 4 and July 17, 1979. Analyses reiterate previous findings that lowlevel moisture convergence appears to be the principal parameter for establishing a suitable cloud-seeding environment over the Texas HIPLEX area.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS-- Weather modification research/mesoscale data analysis/satellite cloud imagery/weather radar data analyses/radar-echo climatology/rawinsonde observations/precipitation data analysis/cloud seeding

b. IDENTIFIERS-- Texas High Plains Cooperative Program (Texas HIPLEX); Big Spring, Texas

c. COSATI Field/Group COWRR:

18. DISTRIBUTION STATEMENT
Available from the National Technical Information Service, Operations Division, Springfield, Virginia 22161.

19. SECURITY CLASS (THIS REPORT) UNCLASSIFIED	21. NO. OF PAGES
20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. PRICE

GPO 845-630

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TEXAS DEPARTMENT OF WATER RESOURCES

1700 N. Congress Avenue
Austin, Texas

April 10, 1980

Dr. Bernard A. Silverman
Acting Chief, Office of Atmospheric
Resources Management
Water and Power Resources Service
Building 67; Denver Federal Center
Denver, Colorado 80225

Dear Dr. Silverman:

Re: Texas HIPLEX Interim Progress Report

In compliance with Amendatory Agreement No. 1 to Contract No. 14-06-D-7587 between the Water and Power Resources Service (the Service) and the Department, we hereby submit twenty (20) copies of the Interim Progress Report for the Texas High Plains Cooperative Program (HIPLEX). The report discloses and explains all Texas HIPLEX work performed and results achieved during the interim period October 1, 1979 through March 31, 1980.

This report consists of a compilation of individual reports prepared by the Department and each of the Texas HIPLEX participants--Texas A&M University, Texas Tech University, the Colorado River Municipal Water District, Meteorology Research, Inc. and North American Weather Consultants. The individual reports consist of three sections which: (1) describe all activity during the period, (2) outline the work planned for the forthcoming report period. A Table of Contents and Lists of Tables are provided at the beginning of the report for order and ease of reference. An Executive Summary is included for introduction and orientation purposes.

Please direct any questions concerning this report, or the need for further information, to the Department's Weather Modification and Technology Section of the Planning and Development Division.

Sincerely,

Herbert W. Grubb

Herbert W. Grubb
Director, Planning and
Development Division

EXECUTIVE SUMMARY

In 1974 the Bureau of Reclamation (then--Bureau, now the Water and Power Resources Service--WPRS) Office of Atmospheric Resources Management entered into a cooperative cost-sharing agreement with the Texas Water Development Board (one of three predecessor agencies to the Texas Department of Water Resources--TDWR), for the purpose of conducting a long-term, comprehensive atmospheric research and weather modification development program known as the High Plains Cooperative Program (HIPLEX). The overall goal of the HIPLEX program is "...establishing a verified, working technology and operational management framework capable of producing additional rain from cumulus clouds in the semi-arid Plains States." In order to achieve this goal, three field-research sites in the U.S. High Plains region were selected by the then Bureau. One site was located in Montana, another in Kansas and a third in the Big Spring-Snyder area of West Texas. The Texas HIPLEX program has been and continues to be managed by the TDWR under the overall guidance of the WPRS.

To date, the objective of the Texas HIPLEX program has been to understand more fully the cloud and precipitation processes associated with natural and seeded clouds which develop in the High Plains of Texas. This objective is being accomplished through the cooperative efforts of the following Governmental and private organizations:

Water and Power Resources Service
Texas Department of Water Resources
Texas A&M University (Department of Meteorology)
Texas Tech University (Atmospheric Science Group)
Colorado River Municipal Water District
Meteorology Research, Incorporated
North American Weather Consultants

This report presents the work performed by the TDWR and its subcontracting organizations during the six-month period from October 1, 1979 through March 31, 1980.

The report discusses the TDWR's continuing role as manager and administrator of the Texas HIPLEX program. The TDWR negotiated, awarded, and/or administered nine subcontracts with other Texas HIPLEX participants during the report period. The TDWR assisted in the development of the 1980 field operations plan and provided staff meteorologists who served to organize and oversee several Texas HIPLEX planning meetings and conferences.

Services provided by the Colorado River Municipal Water District (CRMWD) are discussed. In brief, the CRMWD maintained an extensive network of recording and non-recording rain gages as well as provided a summary of the mesoscale rawinsonde data collected during the 1977-78 Texas HIPLEX field seasons.

Texas A&M University (TAMU) provided data reduction and evaluation services to the program on the mesoscale and cloud physics levels, as well as providing Chief Scientist support. The salient findings of these studies are presented.

Also, TAMU conducted work in an effort to establish a Synoptic Climatology for the Texas HIPLEX region. Findings from this study are discussed.

Texas Tech University's (TTU) work with satellite and precipitation data is presented, as well as preliminary studies regarding data acquired with the Skywater radar during the 1979 field program.

Finally, work performed by Meteorology Research, Incorporated (MRI) to prepare the 1976-78 M-33 Snyder radar data for use by North American Weather Consultants (NAWC) is discussed, as well the progress by NAWC in the analysis of these data. MRI's work includes extensive software reworking and preparation.

The importance of this research concerning West Texas summertime cumulus clouds and their environment must be stressed so that a high priority may be placed on the collection and analysis of data pertinent to the processes involved in these clouds and cloud systems. An understanding of the causes and effects of cloud behavior, both seeded and unseeded, must be achieved with a high level of confidence for the Texas HIPLEX area so that the predicted changes in seeded clouds over the Texas High Plains, and their resulting rainfall behavior, may be verified.

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TEXAS DEPARTMENT OF WATER RESOURCES

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Contract Administration

During the October 1, 1979 - March 31, 1980 reporting period the Department awarded or negotiated a total of four new contracts in support of studies and operations related to the Texas HIPLEX Program. Additionally, five contracts in force as of October 1, 1979 were administered in support of the Program. A summary of these contracts is shown in Table 1.

Table 1. Contracts Awarded by the TDWR in Support of the 1979 Texas HIPLEX Program.

Contract No.	Organization	Period		Purpose
		Begin	End	
14-90027	Colorado River Municipal Water District	1-79	12-79	Operation of raingage network, rawinsonde and radar; equipping and operation of Aztec and p-Navajo aircraft
14-00004	Texas Tech University	9-79	12-79	Analysis of 1977 and 1978 satellite data; 76-77 precipitation analysis; collection of 1979 radar data and real-time satellite imagery
14-00003	Texas A&M University	9-79	12-79	Analysis of 1978 mesoscale data, development of water budget models, entrainment model, determination of environmental response to convective activity, cloud physics, conduct field program and Chief Scientist support
14-00005	Texas A&M University	9-79	12-79	Synoptic climatology for Southern HIPLEX; resolution of the radar-bias problem; fine-scale seeding effects analysis
14-00013	North American Weather Consultants	8-79	6-80	Analysis of 1976-1978 Texas HIPLEX digital M-33 radar data
14-00025	Meteorology Research, Incorporated	12-79	6-80	Preparation of M-33 radar data for analysis; movement of M-33 equipment
14-00026	Texas Tech University	1-80	12-80	Same as (14-00004) above
14-00027	Colorado River Municipal Water District	1-80	12-80	Same as (14-90027) above
14-00030	Texas A&M University	2-80	1-81	Same as (14-00003) above

Meetings and Texas HIPLEX Management

Several Texas HIPLEX planning meetings were held at various sites during the reporting period for the purpose of assessing and evaluating current findings--particularly in relation to the Intensive Case Study days of June 4, 1979 and July 17, 1979--with regard to Texas HIPLEX oriented research.

A Texas HIPLEX planning meeting was held in Austin October 22-23, 1979 for the purpose of developing the FY 80 and FY 81 Texas HIPLEX budgets. Representatives from each of the program-related participants were in attendance. Proposed block-type budgets were prepared, and a letter containing cost breakdowns was provided for WPRS representative, Dr. Arlin Super, who was in attendance.

A similar meeting was held at College Station on December 4, 1979 for the purpose of reviewing the FY 80 and FY 81 budgets. In attendance were representatives from each Texas HIPLEX subcontractor. It was determined that budgets must be restricted to allow for decreased Federal funding.

A Texas HIPLEX conference was held at Austin on March 25, 1980 for reviewing the salient findings pertinent to the Intensive Case Study days (see above). Representatives from all Texas HIPLEX participating groups, except North American Weather Consultants and Meteorology Research, Incorporated were in attendance. Also present was Mr. David Matthews of the WPRS.

Reports

A number of Texas HIPLEX-related publications have been prepared either by Department staff or Texas HIPLEX participants during the reporting period of October, 1979 through March, 1980. These are listed in the table below:

Title	LP#	Contractor	Pub. Date
Texas HIPLEX Interim Progress Report	110	Staff	Dec. 79
Texas HIPLEX Field Operations Summary	112	Staff	Jan. 80
Models of Atmospheric Water Vapor Budget for the Texas HIPLEX Area	117	TAMU	Feb. 80
Texas HIPLEX Mesoscale Experiment--Summer 1979 Data Tabulations	118	TAMU	Feb. 80
Processing of the M-33 Snyder, Texas Radar Data	120	MRI	Mar. 80
A Synoptic Climatology for Southern HIPLEX	121	TAMU	Mar. 80
Mesoscale Characteristics of the Texas HIPLEX Area During Summer 1978	123	TAMU	Mar. 80
Preliminary Cloud Microphysics Studies for Texas HIPLEX 1979	124	TAMU	Mar. 80

Additionally, Texas Tech University submitted a Texas HIPLEX-oriented report pertaining to their radar, precipitation and satellite imagery studies. This will be distributed upon its publication in early May.

TEXAS A&M UNIVERSITY

1. Mesoscale Characteristics of the Texas HIPLEX Area
2. A Radar Echo Climatology for Southern HIPLEX

Mesoscale Characteristics of the Texas HIPLEX Area

1. Meso-and Synoptic-Analyses

A report entitled "Mesoscale Characteristics of the Texas HIPLEX Area During Summer 1978" (Sienkiewicz, et al., 1980) was completed and forwarded to the Texas Department of Water Resources in March 1980. This report contains an analysis for twenty-six days on which mesoscale meteorological data were obtained in the Texas HIPLEX area during the period June 1 through July 26, 1978. Sounding data were available for 17 of the 26 days from Midland, Robert Lee, Post, and Big Spring. Surface data were available for all 26 days from 20 stations. Radar data from the National Weather Service radar at Midland were used to locate convective activity.

The same procedure was followed as in previous years in the analysis of the data. Results were presented for each day separately, and composite analyses of surface variables and selected upper air variables associated with convective activity also were presented. Numerous variables for both surface and upper levels were analyzed and charts of analyzed fields presented. Pronounced interactions between the environment and convective activity were indicated, which is consistent with and supports similar analyses for the 1976 and 1977 data. Results for all three years show the importance of the lower atmosphere, including the surface layer, as a source region for initiating and maintaining convective activity. The principal energy source for the convective activity appears to be horizontal moisture convergence below 3 km, which is accompanied by vertical transport of the moisture from the lower to the mid troposphere.

Analysis of the 1979 mesoscale data was begun. The approach to be followed in the analysis of the 1979 mesoscale data is different from those performed in previous years in that upper air data will be gridded. The number of sounding stations for 1979 was seven as compared with four during previous years; this makes a gridding procedure possible. Upper-level results are now available for July 17, 1979 using the gridding procedure, and the results are encouraging. Spatial variations in mesoscale systems at each sounding time are shown in the data and, in some instances, it appears that temporal continuity is present even over the 3-hour periods. However, much analysis and interpretation remain to be done from the 1979 data before conclusions are reached.

Synoptic charts have been prepared for July 17, 1979 for a 10-state region surrounding the HIPLEX area. Times for which the synoptic charts have been prepared are 1200 and 0000 GMT, the times encompassing the mesoscale soundings. Synoptic charts were prepared for the surface, 850-, 700-, 500-, and 300-mb levels and radar composite charts were obtained from the Texas A&M University archives for use with the synoptic charts. Also, synoptic charts are in preparation for June 4, 1979 and will be prepared for July 3 and 5 during the next report period.

Four HIPLEX-related papers were presented at conferences. Three of these were presented at the Weather Modification Conference in Banff, and one at the Severe Storms Conference in Kansas City.

2. Water Vapor Budget Models

A report entitled "Models of Atmopsheric Water Vapor Budget for the Texas HIPLEX Area" (Williams and Scoggins, 1980) was published as

Texas Department of Water Resources Report No. LP-117. This report contains water budget models for the Texas HIPLEX area for convective and nonconvective conditions as a function of echo height, areal extent, and type of convective activity. A comparison of the models indicates that greater amounts of water vapor are processed as the depth and areal coverage of the convective activity increase. Also, the budgets show that the net horizontal transport of water vapor exceeds other terms in the equation and represents a primary moisture source for all cases of convection. During periods of heavy precipitation, the net horizontal transport term nearly balances the residual term, thus making the net horizontal transport term the main source of water vapor for precipitation formation. Except for some refinements, no further work is anticipated on the water vapor models.

3. Entrainment

Work on the development of a model for entrainment began more than a year ago but has not advanced very far. Theoretical calculations have been made to demonstrate that entrainment can have a large effect upon the characteristics of convective clouds in the Texas HIPLEX area, but because of a lack of appropriate field data prior to 1979 it was not possible to verify any of the theoretical concepts. A model has been formulated in principle but has not been developed to the point where it can be validated. The mesoscale, aircraft, and radar data collected during the 1979 field program should make is possible to pursue this topic on a meaningful basis and be able to evaluate the validity of an entrainment model.

4. Determination of Environmental Response to Convective Activity

Progress was made on the determination of environmental response to convective activity. Several methods for delineating thunderstorm effects in mesoscale sounding data were investigated and an analysis technique using time cross-sections was chosen. Eighteen preliminary case study days from 1976-78 were reviewed and June 5, 1978 was analyzed. It was determined that additional radar products in the form of CAZMs, RHIs, and higher resolution PPI scans that were available for 1976-78 were necessary to delineate the geometry and development of thunderstorm echoes. Thus, emphasis was placed on data taken in 1979 due to the availability of radar products for that year. Analysis of July 17, 1979 is nearly complete and analysis of June 4, 1979 is underway. Some results from the analysis of June 5, 1978 and July 17, 1979 were presented at the March 25 HIPLEX meeting in Austin.

5. Cloud Microphysics

Efforts in cloud physics were concentrated on analysis of the 1979 MRI Navajo aircraft data and on processing of the 1979 p-Navajo aircraft data.

The analysis conducted of the 1979 MRI Navajo data was summarized in a Technical Report to the Texas Department of Water Resources entitled "Preliminary Cloud Physics Studies for Texas HIPLEX 1979," (Long, 1980). Results of "case-study" analyses for HIPLEX Mission 1 on June 4, 1979 are presented, and of the mesoscale mapping mission of July 17, 1979. Both missions were selected for emphasis by Texas HIPLEX participants. The report also includes a study of precipitation mechanisms in all clouds sampled in 1979 for which data were available at the time. This study suggests that in clouds in the Texas HIPLEX region the development of the ice phase is strongly associated with significant amounts of precipitation. The evidence from another preliminary study of ice multiplication did not provide support for or against this process operating in the sampled clouds.

Processing of the p-Navajo data was completed. A computer terminal was obtained from the Big Spring site and used to communicate with the WPRS computer in Denver. Processing mainly involved correcting the raw data for errors in original recording. The final processed data for all of 1979 have been stored on a single archive tape at the WPRS. Documentation of the processing program and of the processed data has been supplied to the WPRS.

6. Radar

An initial objective of our radar analysis program has been the modification of a Texas A&M University computer program to produce base tilt reflectivity maps and constant altitude reflectivity maps (CAZMs) at 4, 8, and 12 km as well as other selected levels. At this time these derived products have been generated from volume scans corresponding to the sounding times for July 17, 1979. These products support the mesoscale analyses. In addition to these, three additional volume scans near two of these sounding times have been processed to provide radar analyses with more desirable time continuity for the convection/environment interaction study. We are currently producing CAZMs for the sounding times on the other three case study days.

7. Field Experiments

A report entitled "Texas HIPLEX Mesoscale Experiments - Summer 1979 Data Tabulations" (Williams and Gerhard, 1980) was submitted to TDWR for publication. This report described the mesoscale experiment conducted in 1979 and presents data for five manual surface stations and seven rawinsonde stations. The surface data consists of five-minute averages of temperature, relative humidity, and pressure for each hour on the hour for the period June 20 through July 20, 1979. The rawinsonde data were presented at 25-mb intervals for 23 operational days during the period May 21 through July 18, 1979. In addition, radar-observed convective activity taken from the NWS Midland radar were presented for each day for the period May 21 through July 19, 1979. Much of the data presented in this report was processed during this report period, and the data report referred to above and a magnetic data tape were prepared and provided to TDWR.

Preparations were begun during this report period for the 1980 field experiment. Arrangements have been made to acquire five rawinsonde units on loan from NASA and plans have been made to acquire instrumentation for 16 manual surface stations to replace the 25 automatic weather stations originally planned for the experiment. Personnel have been identified who will participate in the field program and a training program has been developed and begun.

8. Chief Scientist and Scientific Advisory Activities

Dr. James R. Scoggins served as Chief Scientist for the Texas HIPLEX program through January 1980 and since that time as Scientific Advisor to TDWR personnel. A close coordination has been maintained with TDWR personnel and numerous functions of an advisory and planning nature performed. The Chief Scientist/Scientific Advisor planned and presided at two meetings of HIPLEX scientific personnel during the report period.

A Radar Echo Climatology of Southern HIPLEX

A study was conducted by TAMU on the synoptic climatology of the Southern HIPLEX. Additionally, a correction for radar bias was developed from Plan Position Indicator (PPI) films recorded at the Amarillo National Weather Service (NWS) WSR-57 radar. These data were compared with that which was developed previously from similar Midland NWS radar data, and an attempt was made at determining the effects of seeding on convective cell characteristics as deduced from radar echoes.

A synoptic climatology of Southern HIPLEX was prepared by a subjective analysis of surface and upper air features. An objective climatology based on surface and upper air variables also was constructed by means of principal components analysis and a weather typing scheme. Each day of the four convective seasons (April-September) of 1973-1976 was typed according to these two methods and separate climatologies were prepared. These climatologies were then compared and each was associated with characteristics of radar echoes, such as number of echoes per day, durations of echoes, and their patterns and movement.

A correction for the tendency of radar to discern echoes differn-tially with distance was developed from observations of 40 months of PPI films from Amarillo and then compared with the same correction developed earlier from Midland films. A middle distance maximum was verified, but the correction curves are otherwise different. It was concluded that an accurate representation of the geographic variation of echo occurrence in Southern HIPLEX is very difficult to establish from PPI films of WSR-57 radars.

The fine-scale analysis of seeding effects, a feasibility study, showed that there was not a sufficient number of seeding missions for which seeded echoes could be distinguished from nonseed echoes so that characteristics of the former could be specified.

This completes all tasks prescribed in Department Contract No. 14-00005 between the Department and TAMU. No further work will be performed.

TEXAS TECH UNIVERSITY

Satellite Data Processing and Analysis

Several accomplishments in satellite research have been achieved through the analysis of four case study days selected from the 1977 Texas HIPLEX field season--June 22, 24 and 27 and July 8, 1977. These four days were selected because of the availability of good satellite, raingage and radar data sets. On two days, July 8 and June 22, substantial rainfalls occurred; on June 24 and 27, however, little or no precipitation was recorded within the raingage network. The objective of this work was to derive cloud properties from the satellite data and then compare and contrast results between rainfall and non-rainfall days.

The percent cloud cover was computed as the ratio of the number of data points within the cloud boundary, determined by the critical visible value, to the total number of data points within the study area. On June 22 cloud cover exceeded 80 percent much of the day. High percentage cloud cover also occurred during the late afternoon of July 8. The early afternoon of both June 24 and 27 was dominated by small isolated clouds, which kept the cloud cover small and even clear for the first four times on June 27. But, on both days in the late afternoon, a storm moved into the study area from the west, contributing to increased cloud cover over the study area. Of interest are the contrasting cases of high percentage cloud cover contributed by only a few clouds and low percentage cloud cover despite the presence of many clouds. The cloud cover at 2045 GMT, June 22 was 87 percent, although there were only 5 separate clouds at this time. The percent cloud cover at 1845 GMT, June 24 was only 6.1 percent, despite the presence of 60 clouds in the study area.

Comparisons were made of percent cloud cover and cloud numbers derived from satellite radiance data and from photographic imagery at one-hour intervals. Although agreement between the two sets of results were generally good, there were some instances of poor agreement. In the original analysis of the photographic imagery, the study was divided into nine sub-areas. These individual values of percent cloud cover were then averaged to produce a more representative overall estimate. Further, the number of isolated and widespread clouds for the whole study area was obtained by adding the numbers from each sub-area.

The agreement of percent cloud cover between the two sets if good, except for a few cases on June 24. Because the percent cloud cover from photographic imagery was estimated visually, it was difficult to maintain as consistent an accuracy as with percent cloud cover derived from radiance data. In general, the difference in percent cloud cover estimated from these two data sets was approximately 5 percent to 10 percent. The most difficult estimates of percent cloud cover occurred at times when isolated, clustered or linear cloud orientation was predominant. This situation was particularly true on June 24.

The agreement in number of widespread clouds between these two data sets was much better than that for isolated clouds. Especially on June 24, when isolated clouds dominated, the agreement was very poor. A detailed study of the results on this date points to an explanation. The computer cloud summary program treated many small clouds as a single large cloud as long as the individual clouds were linked together at even one point. As a result, the number of widespread clouds was one or two more than the value derived from the imagery. Early on July 8, the number of isolated clouds differed for the same reason, although the numbers of the widespread clouds were nearly equal.

The satellite-derived cloud properties described above have been compared with raingage and radar data in an effort to establish the reliability of the satellite results. All four case study days were treated; however, the presentation here will be limited to a single day, July 8. A complete discussion of the four case study days will be given in a technical report to be submitted in the near future. Utilizing the available satellite, radar and precipitation data, a comparison was made by placing the three different data sources into a common coordinate system. The reference coordinates have been selected to be the rectangular array of visible satellite radiance measurements used in this study. The objective of this comparison was to enhance understanding of (a) the structure of the convective clouds (b) the relationship between organized mesoscale features and the synoptic scale (c) storm development processes, and (d) precipitation mechanisms.

At 1845 GMT on July 8, the most intense rain area was located under the brightest and coldest cloud tops within which the cloud albedo was larger than 0.63 and the corresponding cloud top height was above 13 km. More than 0.5 inch of rain had occurred within the previous 15 minutes. A strong rain band along a line from Snyder to Big Spring formed soon after the rain began. The maximum precipitation occurring within the rain band was located under clouds with either high albedo or high tops, or both. The rainfall intensity increased sharply after 1915 GMT when the clouds over the raingage network developed tops to approximately 14.5 km and the area of albedo greater than 0.63 increased considerably. The precipitation peak was reached just before 2000 GMT. Meanwhile, at 2015 GMT the raingage network was totally covered by bright and high-topped clouds with albedos over 0.63 and top heights above 15 km. The

PPI digital radar analysis also indicated that the reflectivity gradients within the rain band became quite sharp, attaining values greater than 55 dBz at this time. The rainfall intensity decreased rapidly after the precipitation peak, and little precipitation was recorded after 2130 GMT.

Four RHI cross-sections at 2018 GMT along azimuth angles 211^o, 223^o, 253^o and 259^o were studied because each of them passed through an intense storm. The minimum detectable signal at this time was about 17 dBz, resulting in considerably higher radar echo tops, reaching 13 km, than were seen at 1942 GMT. The satellite-derived cloud top heights were closer to the radar reflectivity heights at this time because of the smaller detectable signal.

A case of special interest was displayed in the cross-section for an azimuth angle of 259^o. This case is discussed here because the most intense reflectivity at this time occurred along this line. A strong storm cell with large reflectivity gradients was located 35 km from the radar site. This cross-section was along the edge of the rain band mentioned before. The cloud top heights from the infrared radiances varied from 11 to 12.5 km over two intense storm cells, but decreased rapidly beyond the third storm cell which was located about 80 km from the radar. The agreement between the satellite cloud top heights and radar reflectivity was good along this cross-section. A strong reflectivity maximum of more than 60 dBz was located 35 km from the radar site. It is probable that heavy rain did occur under this intense echo which occurred within the raingage network, but there was no raingage located exactly along this direction. This example illustrates the restrictions associated with interpreting rainfall measurements even from a raingage network with rather dense spacing, and points to the desirability of higher resolution data sources such as radar or satellite measurements.

The comparisons made in this study demonstrate the consistency of results derived from satellite radiance measurements with analyses of radar and raingage data, thereby establishing the usefulness of satellite data in the absence of radar or raingage measurements. Further, we have established the reliability of satellite radiance data when compared with radar and raingage measurements. However, the problem of working with observations from three systems with such different spatial resolution was formidable. The superposition of patterns in this study was performed subjectively by hand. Techniques which utilize an objective computer-based approach are becoming available and should permit more ambitious efforts in the future.

During the last two months emphasis has been transferred to analysis of 1979 data. Cloud population information continues to be extracted from the laserfax imagery acquired during the field program. Several days have been selected for detailed investigation: May 20, June 4 and July 17. Radiance data have been given a preliminary examination with the ADVISAR at Colorado State University; further analysis will continue during the next several months.

<u>Radar and Rainfall Data Processing, and Analysis</u>

During the period October 1, 1979 through December 31, 1979 analysis of radar and rawinsonde data continued for the July 8, 1977 case study. The paper titled "Structural similarities between mesoscale convective systems over the Texas South Plains during HIPLEX and over the tropical ocean during GATE" summarizes this analysis of the 1977 data. The text of the paper is included in the 1979 Texas HIPLEX final report. It is also included in the Preprint Volume of the 19th Conference on Radar Meteorology, sponsored by the American Meteorological Society.

During the period January 1, 1980 and March 31, 1980, analysis of the July 8, 1977 data continued, but special emphasis was placed on the analysis of data for the July 17, 1979 Case Study Day. Preliminary results were presented at the Texas HIPLEX scientific meeting in Austin on March 25. The following preliminary findings have been obtained from analysis of data from July 17, 1979.

(1) The precipitation pattern observed on July 17, 1979 nearly coincided with a slowly moving cold front at the surface. This finding suggests that frontal dynamics cannot be ignored in our description and analysis of the mesoscale events on that day.

(2) The amount of precipitation observed in the raingage network on July 17 (98,000 acre-ft) establishes it as a major precipitation event over the network. It is becoming clearer and clearer that frontal systems are major precipitation producers over West Texas in summer. In this connection, Eric Pani, under the supervision of Dr. Haragan, has chosen to undertake an M.S. thesis project aimed at establishing parameters (e.g. storm duration, precipitation rates, mesoscale triggering mechanisms) that define a storm classification scheme which could be used to generate a long-term record of precipitation events for use in

hydrological models.

(3) The movement of radar echoes on July 17 was towards the south at a speed of about 10 kt, approximately that of the cold front at the surface. Both the frontal motion and the echo motion correspond better to 700 mb winds than to winds at 850 mb, or higher levels. This suggests a steering level of about 700 mb.

(4) The radar echo pattern did not possess a well-defined "leading edge" of intense precipitation as does, for example a squall line. Such a lack of structure and organization is consistent with the rather slow propagation of the cold front and the echo features, as well as the relatively light steering-level winds.

(5) The synoptic situation (cold frontal) and precipitation pattern on July 17, 1979 showed several features in common with the July 8, 1977 case study. These features include:

   a. The presence of deep convective cells within indications of overshooting in the upper troposphere.

   b. Large areas of horizontally uniform precipitation possessing radar bright bands in the melting layer late in the life of the precipitation system.

   c. Temperature and humidity soundings indicative of mesoscale unsaturated downdrafts associated with the evaporation of falling precipitation in the region of horizontally uniform precipitation.

This finding suggests that the results of our two case studies will have applicability beyond the two cases themselves. We may, in fact, be able to construct a conceptual model of intense (but not severe) convection associated with summertime frontal systems over West Texas.

Michael Lepage has undertaken an M.S. thesis under the supervision of Dr. Leary. His research will center on the July 17, 1977 case study, with an emphasis on quantifying the role of evaporation in the water budget of the precipitation features observed on that day and in establishing the role of frontal dynamics in the mesoscale convective system which produced the observed precipitation pattern.

COLORADO RIVER MUNICIPAL WATER DISTRICT

During the period October through March, the CRMWD performed routine surveillance of the Belfort recording raingages. Each recording gage was visited weekly to prevent vandalism and to assure that the protective covering on each gage had not been removed. As part of the 1979 winterization program, each gage had its clock, silicone oil and collection bucket removed. On Monday, March 10, 1980, two CRMWD technicians began dewinterizing the gages in preparation for the 1980 Texas HIPLEX program. In addition to installing the component parts removed earlier, the technicians performed weighing and timing calibration tests for each gage. By March, all 108 Belfort gages had been visited and serviced. Presently, recording gage charts are being reviewed to assure proper calibration.

Due to vandalism there is one recording gage (TH-5) which is nonoperable at this time. This gage will be made operable as soon as its replacement parts arrive from the WPRS.

In addition to the 108 Belfort recording gages, the CRMWD has also implemented on March 3 and 4 its network of 81 fencepost (nonrecording) raingages.

Letters of Agreement were initiated by the CRMWD to the Colorado International Corporation (CIC) for the purpose of 1) modifying, updating and calibrating the Texas HIPLEX cloud physics package, 2) installing a PMS 2-D probe onboard the p-Navjo, and 3) leasing a PMS FSSP probe for the collection of cloud droplet data.

On March 24 the Skywater radar van arrived and was again located at Howard County Airport. Data receiving lines for the satellite facsimile were installed on March 28 by Southwestern Bell.

METEOROLOGY RESEARCH, INCORPORATED

1. Reassemblage of the M-33 Digital Electronics at Snyder, Texas
2. Processing of the 1978 Texas HIPLEX Aztec Aircraft Data

Reassemblage of the M-33 Digital Electronics at Snyder, Texas--Task 1

Mr. Robert Schaff of Small Systems Specialities, under subcontract to MRI, transported several pieces of the M-33 DVIP and Quality Control systems to the M-33 radar site at Winston Field, Snyder, Texas. Among these pieces were:

DVIP System

a. 2 magnetic tape recorders

b. 1 data formatter

c. 1 rack

Quality Control System

a. 1 LSI-11 minicomputer

b. 1 Decwriter II line printer

Other pieces returned to the site included:

a. 1 generator, signal 800-4000 mc (Property No. 3387.0.0046)

b. 1 meter, frequency FRY MUI, N-410A (Property No. 4810.0028)

c. 1 Variometer 400/6 (Property No. 4865,0321)

DVIP system hardware pieces were assembled with the Illinois State Water Survey VIP processor. The Quality Control and Video Recording systems were also assembled. The meter, Triplett 5020, SN-1032 (Property No. 4865.0.0254) was identified at the radar site to Mr. Robert Riggio of Department staff.

This completes Task 1 of the contract.

Processing of the 1978 Texas HIPLEX Aztec Aircraft Data--Task 2

The thirteen magnetic tapes containing 1978 Aztec data were obtained from the WPRS, and work has begun on collecting all necessary calibration and intercomparison data from the MRI Navajo. A review of the calibration procedures and the computer programs has also begun.

NORTH AMERICAN WEATHER CONSULTANTS

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Data Processing

The digitized radar data were recorded on magnetic tape. Tapes were then pre-processed at Meteorology Research, Incorporated (MRI) to change the data format to one compatible with data recorded by Skywater SWR-75 radars on other HIPLEX projects. The pre-processed data were then sent to the University of North Dakota (UND) for final processing through existing HIPLEX software (see Schroeder and Klazura, 1978).

Processing at UND led to the creation of the following data that will be used at NAWC for this analysis:

- U-Files, which contain on tape all radar information on each case identified by the cell-tracking program. The cell-tracking program associates each separate echo exceeding a particular reflectivity threshold with a case identification number. Each case is then tracked on subsequent radar scans until the case dissipates, merges, or moves out of range. The reflectivity threshold was 10 dBz for the 1976 radar data and and 20 dBz for the data collected in 1977 and 1978.
- DBZ-Files, which contain on tape equivalent radar reflectivities along each recorded azimuth at each antenna elevation step.
- Microfiche of composite PPIs and echo tops, which show maximum reflectivities or echo top heights in a radar scope-type presentation.

- Microfiche of the case study summary files, which have sorted information on each case (as opposed to the unsorted information available on the U-files). The sorted information includes such parameters as case volumes segregated by reflectivity categories, case centroid location, maximum height, and average and maximum reflectivities for each volume scan. Also available are case areas for each elevation angle of the volume scan.

Delays have been encountered in obtaining the processed radar data. One problem causing a delay was that about one-tenth of the pre-processed tapes contained excessive errors when processed by UND. Those tapes were re-processed at MRI to remove the problem. Another more serious delay-causing problem was radar calibrations for the 1977 and 1978 data. The calibrations, which relate the recorded DVIP units to power returned, were done over a relatively small range of power units and were expressed in a cubic regression equation. As a result, high DVIP values led to extremely high radar reflectivities (on the order of 80 dBz). Consultations among the various participants resulted in the decision to use a linear calibration equation instead of the cubic equation used previously. The radar data were then reprocessed with the new calibration equations.

NAWC obtained the reprocessed U and DBZ-Files in February 1980. Microfiche of composite PPI and echo top heights, which were produced by the WPRS using processed data from UND, were received in March 1980. Yet to be received are the microfiche of the case study summary files. These microfiche should be available in April 1980.

Preliminary Work

Before work could begin on the four tasks described above, a certain amount of preliminary work was required. This included acquiring auxiliary data, developing software, checking data quality, categorizing the radar data into echo types, coding each day according to weather patterns, and identifying seeded cases. These topics will be discussed below.

Acquisition of Auxiliary data

Although the M-33 radar data are the primary data required for the analysis, other types of data are also needed. NAWC has obtained the following auxiliary data:

Radar-related reports by the various Texas HIPLEX participants;

Texas HIPLEX data inventories and data tabulations;

Sectional surface weather maps prepared by TDWR;

Seeding logs for 1976-78;

Texas HIPLEX rawinsonde and mesonet data;

National Weather Service rawinsonde data for Midland;

National Weather Service WSR-57 radar films for Midland.

Quality Control Checks

The reliability of the M-33 radar data has been checked by scanning microfiche of composite PPI displays for each scan sequence. This process has identified radar malfunctions labeled as cells by the UND cell-tracking program and bad scan sequences. A list of incorrectly identified cells and bad scans has been included in the master file (see Determination of Seeded Cases).

Scanning through the microfiche has also revealed instances where manual cell re-numbering was required to maintain data continuity. For example, if a serious radar malfunction occurred during a scan sequence and no data were recorded, the cell-tracking program would terminate all cases at the previous scan and identify those same echoes as new cases on the subsequent scan. A list of such instances, including the correct case numbers and time of occurrence, has been compiled and included in the master file.

M-33 radar data have also been checked for data quality by viewing microfilm of the Midland WSR-57 radar when M-33 data were collected. This process provided a general overview of M-33 radar quality, since the two sets of radar data have different thresholds and resolution. In these general terms, the two radars compared very favorably.

All auxiliary data have also been checked for data quality. The magnetic tape containing the 1977 Texas HIPLEX rawinsonde data was found to be unreadable and was replaced.

Identification of Echo Type

Work on Tasks 2 and 4 requires that echoes be classified as either cells, clusters, or lines. After Scoggins *et al.*, (1979), echo types have been defined as follows:

Cell: an individual echo with, at most, two reflectivity peaks.

Cluster: an echo containing three or more reflectivity peaks within a common echo boundary.

Line: An organization of echoes along a common axis.

To facilitate comparison of echo types with parameters computed from the four-station HIPLEX rawinsonde network (such as divergence or moisture flux), echo typing was done only in the project area. Thus, if cells were in the project area and a line was east of the project area, the echo type at that time would be a cell. If more than one type existed at the same time within the project area, the type would be determined from the following ranking: (1) line, (2) cluster, and

(3) cell. That ranking was based on degree of mesoscale organization. Echo types were identified with microfiche of the composite PPI data.

A chronological list of echo types for all days with suitable radar data is given in Table 1.

Classification of Days by Weather Pattern

For use in the performance of Task 4 (relation of echoes to environmental conditions), each day has been assigned a four-character code. This code describes each day in terms of weather patterns at the surface and aloft. Surface weather conditions were determined from sectional weather maps provided by TDWR, while 500-mb maps at 1200 GMT were used to determine conditions aloft. The coding scheme was a slight variation of a scheme used by Texas A&M University (TDWR, 1979).

As shown in Figure 1, the scheme allows four surface weather patterns and six patterns at 500 mb. Surface patterns are further broken down by wind direction, while 500 mb patterns can be long wave or short wave (if applicable).

A list of daily weather codes is given in Table 2. Coding was not done for June and July 1976, since surface sectionals were not readily available and little usable radar data were collected in 1976. The two days with good radar data (June 3 and June 4, 1976) can be considered as C3E1.

Determination of Seeded Cases

The in-depth analysis of seeding effects requires identifying the case number assigned to the seeded cloud by the cell-tracking program. That identification was done by transferring the seeding location from coordinates relative to the Big Spring VOR to coordinates

Table 1. Chronology of Echo Types in Texas HIPLEX Project Area (1976-78).

Date	From (GMT)	To	Type
3 June 76	2043	2203	None
	2203	2338	Cell
4 June 76	1944	2115	Cell
	2115	2235	Cluster
1 June 77	1436	1701	Cluster
	1701	1730	Cell
	1730	0051	None
9 June 77	1903	1928	None
	1928	0003	Cell
	0003	0455	None
11-12 June 77	0146	0229	None
	0229	0600	Line
	0600	0800	Cluster
14 June 77	0500	0602	Cluster
20-21 June 77	0446	0600	Line
	0600	0828	Cluster
21-22 June 77	1723	1800	None
	1800	2230	Cell
	2230	2330	Line
	2330	0334	Cluster
	0334	0431	Line
	0431	0652	Cluster
22 June 77	2219	0357	Cluster
23 June 77	1905	2332	Line
	2332	0057	Cluster
24-25 June 77	1748	1829	Cluster
	1829	2044	Cell
	2044	2154	Missing Data
	2154	0111	Cell
	0111	0304	Cluster
	0304	0630	Line
	0630	0656	Cell
25-26 June 77	1812	1857	None
	1857	2003	Cell
	2003	0633	Cluster
26 June 77	2140	2200	Cell
	2200	2330	None
	2330	0133	Cell
27 June 77	2024	0101	Cell
	0101	0430	Cluster
30 June 77	2130	2200	None

Table 1 (Cont'd)

30 June 77	2200	0001	Cell
	0001	0200	Cluster
8 July 77	1442	1730	None
	1730	1803	Cell
	1803	2138	Line
	2138	0056	Cluster
	0056	0123	Cell
9 July 77	1754	1902	Cell
	1902	2304	Cluster
	0032	0132	Cluster
2 June 78	1445	0223	Cluster
5 June 78	1605	1927	Cell
	1927	1956	None
	1956	2105	Cell
	2105	2220	Cluster
6 June 78	2000	2029	Cluster
	2029	2130	Cell
7 June 78	2202	0001	Cluster
	0001	0021	Cell
13 June 78	1920	2000	None
	2000	2033	Cell
	2033	2204	Cluster
	2204	0004	Cell
28 June 78	2126	2248	Cell
29 June 78	2005	2130	None
	2130	0004	Cell
	0004	0204	Missing Data
	0204	0220	Cluster
30 June 78	2247	0151	Cluster
1 July 78	1946	2047	Line
	2047	2351	Cluster
2 July 78	1952	0139	Cell
3 July 78	1827	1900	Cell
	1900	0110	Cluster
	0110	0444	Line
15 July 78	2147	0025	Cluster
22 July 78	1855	2012	Cluster
	2012	2338	Line
	2338	0125	Cluster
23 July 78	1349	1555	Cluster
	1555	1833	Cell
	1833	0007	Cluster
24 July 78	1716	1820	Cell
	1820	2239	Cluster
	2239	0020	Cell

Table 1 (Cont'd)

26-27 July 78	2029	2143	Cluster
	2143	0055	Cell
	0055	0220	Cluster
	0220	0441	Line
	0441	0529	Cluster

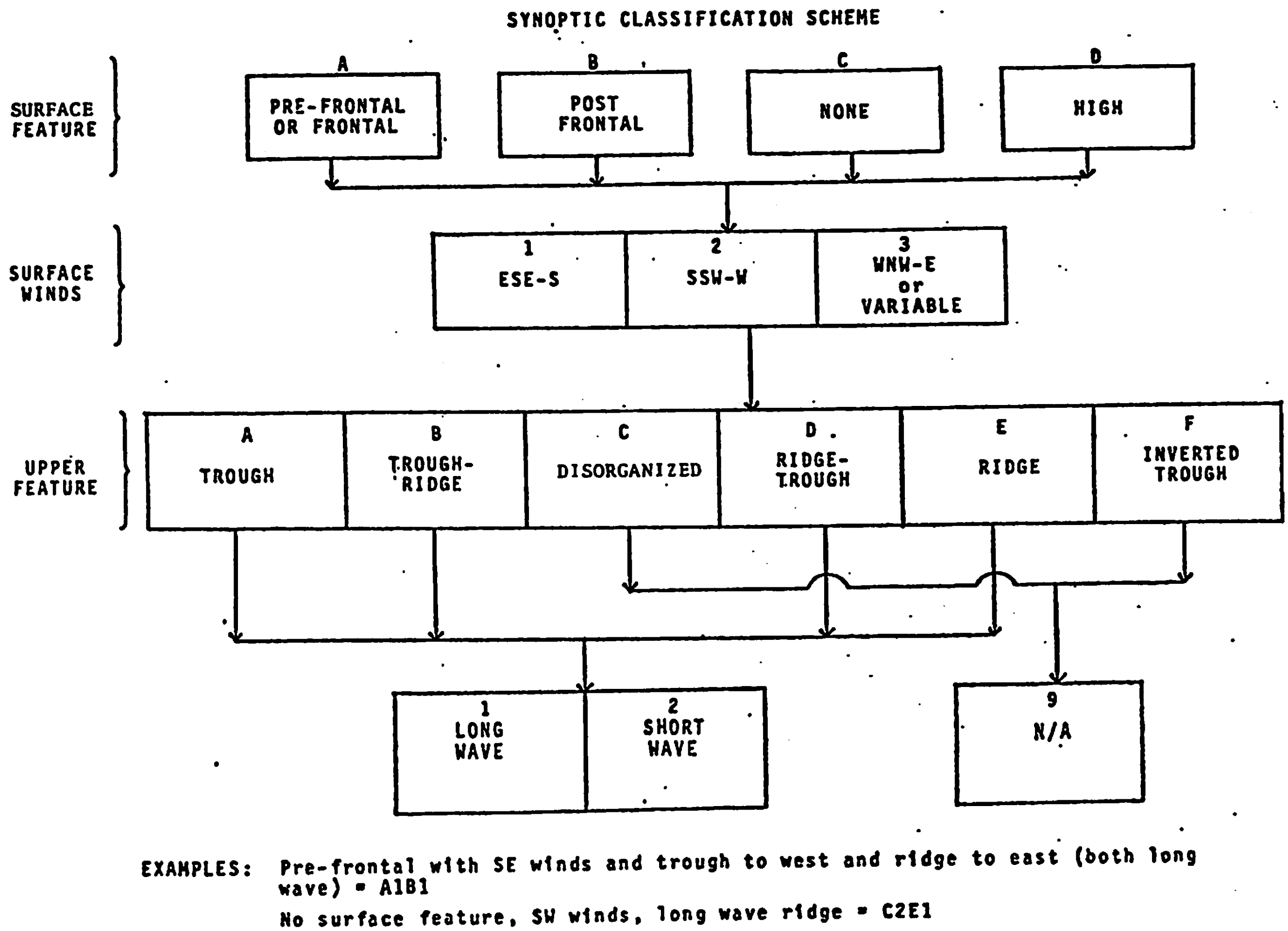

Figure 1. Coding scheme for daily surface and 500 mb patterns.

Table 2. Four-Character Daily Weather Code for June and July, 1977-78. (Refer to Figure 1 for explanation of code.)

Day of Month	June 77	July 77	June 78	July 78
1	B1D1	C1F9	B3A2	A1C9
2	C2D1	C1F9	B3D2	C1A2
3	C2E1	C1F9	B3D2	C3D1
4	C2E1	C1B1	C1E2	C1C9
5	C2E1	C1E1	C3C9	C1C9
6	A2E1	C2E1	C3B1	C1C9
7	B3E1	C2E1	C3A1	C1E1
8	C1E1	A1F9	C3D1	C1E1
9	C2B1	B3F9	C2D1	C1E1
10	C2B2	C2E1	C1C9	C1E1
11	C2B2	C2E1	C2C9	C1E1
12	C3A1	C1E1	A3E1	C1E1
13	C2D2	C1E1	A3E1	C1E1
14	C1E1	C1E1	C1E1	C3E1
15	C3E1	C1E1	C1E1	A3E1
16	C2E1	C1E1	C1E1	B3E1
17	C2E1	C2E1	C1C9	C3E1
18	C1E1	C1E1	C1E1	C2E1
19	C2E1	C1E1	C1E1	C1E1
20	C1E1	C1C9	C2E1	C1E1
21	C2B1	A1F9	C1E1	C1C9
22	C1B1	B3F9	C1E1	A2E1
23	C2B2	C3E1	C1E1	B3A2
24	C2B2	C1E1	C1E1	A3E1
25	A1A2	C3E1	C1E1	C2E1
26	A2A2	A3E1	C1F9	C1C9
27	C1D2	B3E1	C1F9	A3E1
28	C1D2	B3C9	C1C9	B1F9
29	C1F9	B1D1	C1C9	C1F9
30	A2A2	C3D1	A3C9	C1F9
31		C3D1		C1F9

relative to the M-33. Microfiche of the composite PPI were then used to relate each seeded (or randomly not-seeded) cloud to a case number. A total of 29 seeded or not-seeded cases were identified. Of these, 26 were seeded, while three were not-seeded. Three of the 26 seeded clouds never developed an echo, as did one of the three not-seeded clouds. This dearth of unseeded cases will require the non-random selection of unseeded clouds existing nearby seeded cases for comparison purposes.

Development of Master File Software

Performance of two of the four tasks (2 and 4) requires the creation of a master file of all pertinent data. The master file contains M-33 radar data (U-files); Texas HIPLEX rawinsonde data; NWS rawinsonde data for Midland; various sounding-derived parameters; and manually determined parameters such as echo types, daily synoptic weather codes, and identification numbers of rejected and renumbered echoes. The master file thus combines all relevant data into a format which allows easy computer access and manipulation. The software to create the master file has been developed. Program verification with the recently acquired, reprocessed M-33 radar data remains to be completed.

Cloud Characteristics Versus Seeding--Task 1

TDWR has requested intensive radar case studies of selected seeded and not-seeded cells to attempt to determine the effects of seeding. Specifically, investigations of the time histories of the vertical distribution of radar-derived precipitation (including cloud top heights) were requested. This task will be performed by selecting seeded and not-seeded cases and then conducting an intensive investigation of possible effects of seeding, using the case study summary file as the primary source of data. Possible response variables to be investigated include echo top heights, echo growth rates, maximum reflectivities, echo sizes, and echo durations.

Since the microfiche of the case study summary files have not been received, no work has been done on the investigation of seeding effects. As mentioned in "Determination of Seeded Cases," all seeded or not-seeded cases have been identified in terms of case identification numbers.

Generation of Echo Summary--Task 2

Production of echo summaries will result in statistics on such echo parameters as size, motion, depth, and duration. A master file of pertinent radar and rawinsonde data has been developed to compute the statistics.

Software development of the master file has been completed. However, the lack of reprocessed radar data has precluded further work.

Production of Radar-Derived Hourly Rainfall Maps--Task 3

This task consists of the preparation of hourly radar-inferred rainfall maps over an area instrumented with a special precipitation gage network. These rainfall maps are to be computed utilizing radar reflectivities observed at the 1.5 degree elevation angle of volume scan. A pre-determined reflectivity-rainfall rate (Z-R) relationship will be used. That Z-R relationship is $Z = 384R$ 1.61 (Smith _et al._, 1977).

As a result of a request from Texas Tech University, rainfall maps on specified dates will be computed using all radar data ("entire scope"). The rainfall maps for the other dates will be limited to a rectangle with the following radar coordinates (which roughly define the project raingage network): 75 km West to 30 km East and 30 km North to 60 km South.

The software to convert radar data in the DBZ-File to hourly rainfall amounts over the raingage network has been developed. Several types of grey scales have been tried. An example of an hourly rainfall map is shown in Figure 2, which is intended only for illustration of the program output since it was generated with the non-reprocessed data.

Interpretation of Radar Patterns in Terms of Environmental Conditions--Task 4

This analysis consists of a comparison of various environmental and synoptic features with the formation and subsequent behavior of the three echo types --lines, clusters, and cells. The master file created for task number 2 will be utilized in this analysis.

The software to create the master file has been developed. Two preliminary analyses have been performed with the manually determined contents of the master file. These analyses are described in the following sub-sections.

Diurnal Observations of Echo Type. Using the information supplied in Table 1, chronology of echo types, an analysis has been performed to determine during which hours of the day the three echo types were observed. Results are shown in Table 3. The cell and cluster types both have maxima in the late afternoon. The distribution for clusters was,

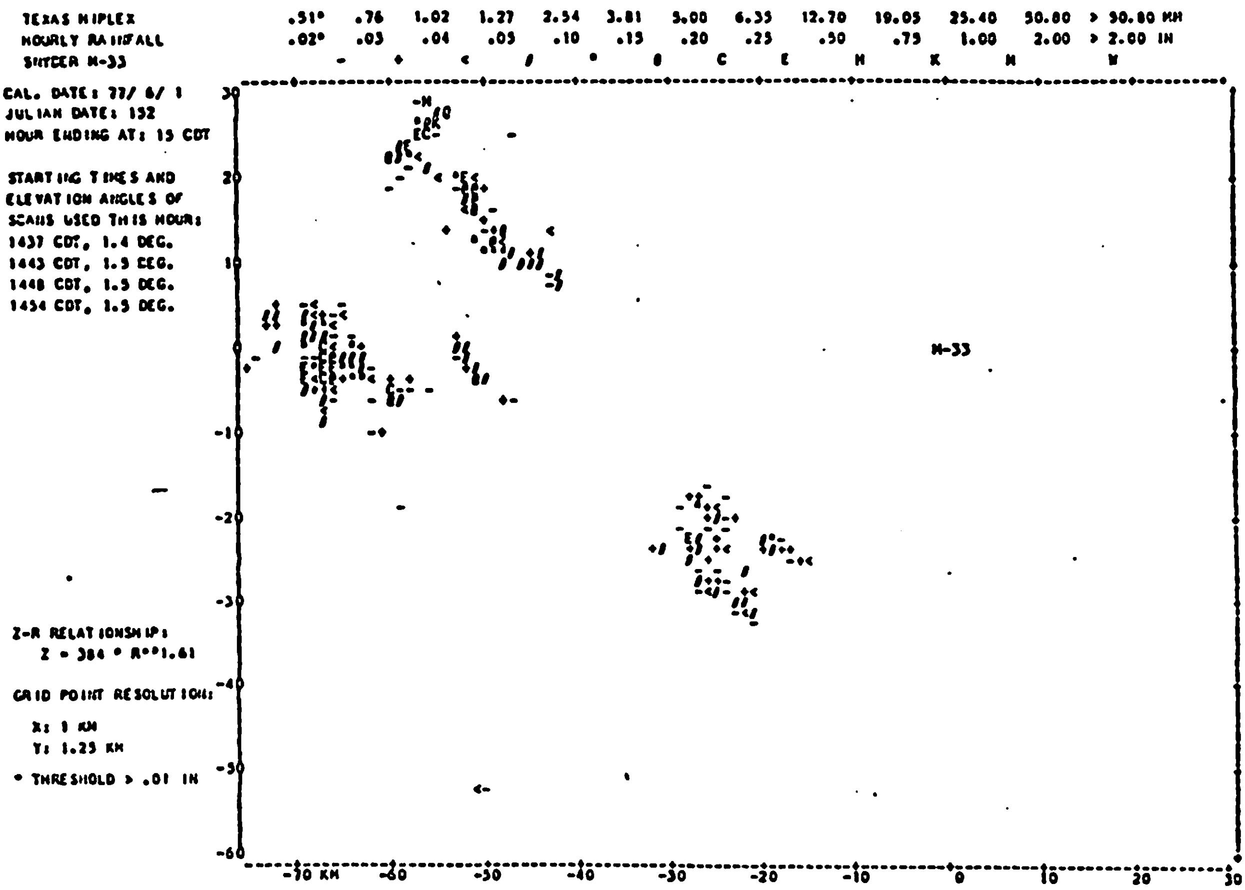

Figure 2: Example of radar-derived hourly rainfall map.

Table 3: Frequency of Occurrence of Daily Priority Echo Type Associated with Surface Weather Patterns.

Surface Pattern

Priority Echo Type	Pre-Frontal or Frontal			Post Frontal			No Front			High Pressure	TOTALS
	Wind ESE-S	Wind SSW-W	Wind Variable or WNW-E	Wind ESE-S	Wind SSW-W	Wind Variable or WNW-E	Wind ESE-S	Wind SSW-W	Wind Variable or WNW-E		
Line	2 days	2	2	0	0	0	2	1	1	0	10
Cluster	0 days	1	3	1	0	4	4	3	5	0	21
Cell	0 days	1	0	0	0	0	4	2	1	0	8
TOTALS	2	4	5	1	0	4	10	6	7	0	39 days

however, much broader. The line echo type was observed bi-modally, with one afternoon maximum and another maximum after sunset.

The non-operational nature of the data collection biased routine late night observation of echoes. Driscoll (1978), using data from the Midland WSR-57 radar, observed echoes during all 24 hours. He did show a late afternoon maximum and a fairly broad minimum between 0500 and 1500 GMT.

Relation of Echo Type to Weather Pattern. An analysis has been performed to determine the association between the occurrence of the three radar echo types and weather patterns (both at the surface and aloft). Data for this analysis consisted of the daily four-character synoptic code and the highest priority echo type observed each day within the project area. Echo types were ranked in descending order of priority as follows: lines, clusters, and cells. These priority rankings were based on degree of echo organization. Days with lines as the priority echo type might also have had clusters or cells occurring during some part of that day. Likewise, days with clusters might have had cells occurring during the day. The priority echo type simply shows the most organized echo type occurring on a particular day.

Results of the analysis of daily priority echo type and surface weather patterns (the first two characters of the synoptic code) are given in Table 3. Of the 39 days with M-33 radar data, clusters were the highest priority echo type observed on 21 days. Clusters were especially likely to be observed with no surface fronts or in post-frontal conditions. Lines were the second most-frequently observed priority echo type. Over half of the days with lines were characterized

Table 4: Frequency of Occurrence of Daily Priority Echo Type Associated with 500 mb Weather Patterns.

Priority Echo Type	Trough Long Wave	Trough Short Wave	Trough-Ridge Long Wave	Trough-Ridge Short Wave	Disorganize	Ridge-Trough Long Wave	Ridge-Trough Short Wave	Ridge Long Wave	Ridge Short Wave	Inverted Trough	TOTALS
Line	1 day	1	1	1	3	0	0	2	0	1	10
Cluster	1 day	2	2	1	2	2	3	6	0	2	21
Cell	0 days	2	1	1	2	0	1	1	0	0	8
TOTALS	2 days	5	4	3	7	2	4	9	0	3	39 days

by pre-frontal or frontal surface weather patterns. Lines did, however, occur in the absence of surface fronts. Cells were the least likely daily priority echo type to be observed, occurring about one-fifth of the time. Seven of the eight days with cells as the highest priority type were non-frontal.

Radar echo type occurrence under 500-mb patterns is given in Table 4. On first inspection, the observed frequencies show little relationship between echo types and 500-mb features. However, when the ridge-trough and ridge patterns are pooled into one "high pressure" pattern, clusters were the priority echo type on 11 of the 15 days. Forming a "low pressure" sample from the trough and trough-ridge patterns shows that, although clusters were still the most frequent, cells and lines were relatively more frequent. Lines were also relatively more frequent when the 500-mb pattern was disorganized.

To put these weather patterns into context, in June and July of 1977 and 1978, the pre-frontal or frontal surface pattern was observed on 15 days and radar data were collected on 11 of those days. Post-frontal patterns occurred on 13 days, only 5 of which had radar data. The most frequent surface weather pattern was non-frontal (94 days), and radar data were collected on 21 of those days. For weather patterns at 500 mb, the low pressure pattern of trough or trough-ridge occurred on 17 days and radar data were collected on 14 days. High pressure (ridge or ridge-trough) occurred on 77 days, primarily in the form of a long-wave ridge, and radar data were taken on only 13 of those days. The other two patterns, inverted trough and disorganized pattern, represented 13 and 15 days, respectively; and radar data were collected on 3 of the 13 inverted trough days and on 7 of the 15 days with a disorganized pattern. Days with radar malfunctions or otherwise non-operational days were not excluded from the analysis. However, the figures quoted should be indicative of expected conditions.

REFERENCES

Driscoll, D.M., 1978: A radar-echo climatology for Southern HIPLEX. Final Report (LP-64) to Texas Department of Water Resources, May 1978, 89 pp.

Schroeder, M.J. and G.E. Klazura, 1978: Computer processing digital radar data gathered during HIPLEX. J. Appl. Met., 17, 498-507.

Scoggins, J.R., G.S. Wilson, and S.F. Williams, 1979: Mesoscale Characteristics of the Texas HIPLEX Area During Summer 1977. Final Report (LP-99) to Texas Department of Water Resources, May 1979, 433 pp.

Smith, T.B., S.M. Howard, and R.L. Peace, 1977: Radar Evaluation of the Big Spring Weather Modification Program. Report (LP-5) to Texas Department of Water Resources, July 1977, 50 pp.

Texas Department of Water Resources, 1979: Texas HIPLEX interim progress report. Report (LP-110) to Bureau of Reclamation, December 1979, 121 pp plus Appendix.

II. WORK PLANNED

TEXAS DEPARTMENT OF WATER RESOURCES

The Department shall continue in its administrative capacity in consonance with the 1974 Master Agreement between the Department and the Water and Power Resources Service (WPRS), as well as continue monitoring contracts for the Texas HIPLEX program during the April - September 1980 reporting period.

The Department shall continue the planning and conduct of various Texas HIPLEX-oriented planning conferences, as well as serving in principal managerial and operational capacities during the field program.

The Department shall serve as principal reviewer and editor for each of the Texas HIPLEX technical reports submitted by participant subcontractors. In addition to publishing technical reports, the Department shall submit to the WPRS monthly and interim Texas HIPLEX progress reports which consist of progress reports submitted by each of the various Texas HIPLEX participants.

The Department is also responsible for the preparation, editing, publishing and distributing of the 1980 Texas HIPLEX Field Operations Plan, as approved by the WPRS.

Finally, the Department is to initiate an ambitious program to prepare a Texas HIPLEX summary report, which shall consolidate the salient findings from each aspect of the Texas HIPLEX research effort beginning with its inception and following through the 1980 field program. Work on this report during the April - September reporting period will consist of the acquisition and assemblage of pertinent data for what is anticipated to culminate in a significant Department publication in January of 1981.

TEXAS A&M UNIVERSITY

During the next report period we expect progress to be made on the analysis of the 1979 meso- and synoptic-scale data, cloud microphysics, environmental response to convective activity, the analysis of Skywater radar data, as well as to participate in the 1980 field experiment and continue to provide scientific advisory services. It is not expected that much, if any, progress will be made on the development of a model for entrainment because of emphasis that is placed on other activities. Much of our attention during the next report period will be on the field program which includes data processing. Following the field program, as much emphasis as personnel and resources allow will be put on the analysis efforts for the remainder of the report period. We expect to have two new graduate students join the program at the beginning of the fall semester which should help to improve progress on the overall analysis effort.

Work will continue on the determination of environmental response to convective activity. Several more cases for detailed study will be chosen and analyzed using the techniques already developed. Results will be compared to models of the kinematic structure of the thunderstorm environment.

The future effort in radar analysis will consist of the generation of detailed reflectivity profiles for cells of interest as well as liquid water analyses of cells selected for study on the case study days. In both products, the scale factors will be optimized for correlation with our other efforts.

In the area of cloud microphysics, data analyses already begun will be completed, the 1980 program of field studies will be executed and new analyses of data collected in 1979 and 1980 will be commenced. Efforts will be focused on completing the already-identified case studies for 1979, namely June 4 and July 17. Case studies of 1979 data to be initiated will include July 3 (HIPLEX Mission 5), and possibly July 5 (HIPLEX Mission 7) and July 8 (HIPLEX Mission 8). The CRMWD p-Navajo data will be used in these case studies. The p-Navajo data also will be incorporated into a study of precipitation mechanisms similar to, but more comprehensive than, that described in the recent Technical Report to TDWR entitled "Preliminary Cloud Physics Studies for Texas HIPLEX 1979."

An important goal of the effort in 1980 will be to collect additional microphysical data on growing cumulus clouds in the Texas HIPLEX study area. Texas A&M University will provide an observer on the p-Navajo and will provide in-flight direction and coordination of this aircraft and the NCAR Queen Air. The overall goal will be to determine the predominant precipitation mechanisms in clouds in the Texas HIPLEX study region and to determine methods for enhancing rain from these clouds. Emphasis will be placed on determining for Texas HIPLEX clouds 1) the importance of the warm-rain process in accelerating the icr process, and 2) the importance of the ice-multiplication process.

TEXAS TECH UNIVERSITY

Work planned for the period April 1, 1980 to September 30, 1980 by Texas Tech University will include both analysis and field work. The field work will involve two major efforts as follows:

(1) Radar Data Collection - This will involve operation and maintenance of the Skywater 5-cm radar. Digital radar data will be collected on all days when convective echoes are present during the 1980 HIPLEX field season. All tapes will be forwarded for processing according to the procedure established during 1979. Whenever possible, radar observations will be made available for guidance in the deployment of aircraft for cloud monitoring and treatment.

(2) Real-Time Satellite Support - Visible and infrared satellite imagery shall be monitored and interpreted at half-hour intervals on a daily basis in support of forecasting and aircraft operations. Satellite imagery will also be incorporated into both the daily weather briefing and the aircraft mission debriefings.

Analysis will include the following tasks:

(1) Investigation of the structure, water budget and precipitation efficiency of mesoscale convective systems.

(2) Investigation of relationships between radar reflectivity measurements and rainfall rates.

(3) Determination of the precipitation efficiency of isolated cumulonimbus clouds.

(4) Analysis of rainfall aimed at construction of storm models for hydrologic application.

(5) Processing of rainfall collected during the 1980 field experiment.

(6) Case-study analysis emphasizing the use of satellite data by matching cloud pairs in successive data sets.

(7) Derivation of a satellite-cloud climatology from 1976, 1977, 1978 and 1979 satellite data which will be compared to radar echo and rainfall climatology.

COLORADO RIVER MUNICIPAL WATER DISTRICT (CRMWD)

The CRMWD is to tabulate precipitation data from its 81-gage network of non-recording fencepost-type raingages, as well as to provide bi-weekly examination and servicing of the 106-gage Belfort recording raingage network. Also, the CRMWD shall provide an alternate radar (FPS-77) and a qualified meteorologist to the Texas HIPLEX program for the purpose of back-up to the Skywater radar and for aircraft monitoring and surveillance.

The CRMWD shall provide a pressurized, turbocharged Piper Navajo aircraft for the Program, along with a full cloud physics package and 70 hours of flying time during the operational season. The aircraft is to perform both cloud sampling and on-top seeding, so 200 30 gram silver iodide ejectable flares are to be provided by the CRMWD for the Program.

METEOROLOGY RESEARCH, INC. (MRI)

MRI is to complete its contracted work prior to July 31, 1980. This work consists of securing calibration methods for the 1978 Texas HIPLEX Aztec cloud-base aircraft data, such as comparable p-Navajo data, then converting the data into engineering units, providing a hard copy of the data and finally performing documentation and a quality check of the reformatted data against the p-Navajo and rawinsonde data.

NORTH AMERICAN WEATHER CONSULTANTS

Test cases for the intensive investigation will be selected by using, as criteria, radar data quality and the list of priority case study days compiled by other Texas HIPLEX participants. Since only three cases were not seeded during the randomization period of 1978, NAWC will attempt to select as not-seeded cases similar echoes that exist relatively nearby seeded cases. This non-random selection of not-seeded cases will give echo pairs for comparison of seeded and not-seeded echo parameters. The selection of not-seeded cases will be hindered by such factors as 1) seeding being done in a small part of a large line, 2) a lack of similar echoes near seeded cases, and 3) separation of not-seeded echoes from seeded echoes to avoid any question of contamination.

When completed, the list of test cases selected for study will be forwarded to TDWR for review. After approval, the test cases will be investigated in depth for possible seeding effects.

The master file software must first be verified ("de-bugged") with the recently obtained reprocessed radar data. After program verification, generation of echo summaries can be conducted. The data set can easily be stratified to obtain statistics based on such factors as echo type, synoptic weather code, time of day, etc. Further cross-stratifications can be made to obtain, for example, statistics on echo duration as a function of maximum echo height.

Development of the statistics will begin in general terms (i.e., frequency distributions of echo dimensions, durations, and motions) and then proceed toward more specific categories.

The existing software will be used as a model for developing the software to produce the rainfall maps over the entire area. In addition, a final grey scale will be selected. Once these two jobs have been completed, the hourly rainfall maps will be produced.

The results shown earlier are indicative of the direction of future work. For example, the diurnal analysis of echo type showed lines occurring with one afternoon maximum and one evening maximum. What were the environmental conditions associated with the two maxima? Did the evening lines migrate into the project area from New Mexico?

The analysis of echo types under various weather patterns showed lines to occur most frequently in frontal situations. However, in similar frontal situations, clusters and cells occurred as priority echo types. What were the environmental conditions associated with frontal clusters as opposed to frontal lines? Are lines not associated with frontal systems of a different structure than lines occurring with fronts?

The partitioning of echo types by surface and 500-mb features will lead to the generation of rawinsonde-derived statistics within each partition. Statistics will also be computed for the three echo types in general.

III. TRAVEL

TEXAS A&M UNIVERSITY

Mr. Steven F. Williams, Research Assistant, made a trip to Denver for the purpose of assisting WPRS personnel with the development of computer programs for real time analysis. He also visited Boulder during the same trip and made arrangements to acquire on loan 14 anemometers and recorders for use in the Texas HIPLEX field program this summer. Mr. Williams brought the equipment to College Station in a U-Haul truck where it is now being refurbished, tested, and checked out for field use.

Eight people, including J.R. Scoggins, A.B. Long, G.L. Huebner, D.M. Driscoll, S.F. Williams, M.L. Gerhard, Nick Horvath, and Ray McAnelly, made a trip to Austin to attend a meeting involving Texas HIPLEX participants. Each person made a presentation at the meeting.

COLORADO RIVER MUNICIPAL WATER DISTRICT

John Girdzus traveled to Austin, Texas on March 25, 1980 for the purpose of attending the Texas HIPLEX planning meeting for the evaluation of progress on the 1979 Case Study days.

IV. PERSONNEL

TEXAS DEPARTMENT OF WATER RESOURCES

Herbert W. Grubb	Director, Planning & Development Division
John T. Carr, Jr.	Chief, Weather Modification & Tech. Section
Robert Riggio	Meteorologist
George W. Bomar	Meteorologist
Thomas Larkin	Meteorologist
William O. Alexander	Meteorologist
William Hanshaw	Raingage Technician

TEXAS A&M UNIVERSITY

James R. Scoggins, Professor	Principal Investigator and Advisory to the TDWR
George Huebner, Professor	
Steven F. Williams, Research Assistant	
Myron Gerhard, Research Assistant	
Ray McAnelly, Research Assistant	
Several students	Technicians
Dennis M. Driscoll	Principal Investigator
Judson Ladd	Resarch Assistant
Alexis B. Long, Associate Research Scientist	

TEXAS TECH UNIVERSITY

Donald R. Haragan	Principal Investigator
Jerry Jurica	Principal Investigator
Colleen A. Leary	Principal Investigator
Mike Lepage	Research Assistant
Eric Pani	Research Assistant
Erik Rasmussen	Research Assistant
James Taylor	Programmer
Christie Cauble	Secretary II

NORTH AMERICAN WEATHER CONSULTANTS

Don Griffith	Project Director
Joe Sutherland	Principal Investigator
Russ Shaffer	Meteorologist
Doug Hughes	Chief Programmer
Ka-Hung Fogg	Programmer
Darryl Paulson	Programmer
Leona Shaffer	Programmer
George Barnes	Meteorological Technician

COLORADO RIVER MUNICIPAL WATER DISTRICT

Owen H. Ivie	General Manager
R. A. Schooling	Coordinator and Supervisor
John R. Girdzus	Radar Meteorologist
Jeffry Benson	Pilot
Richard Halfman	Raingage Technician

METEOROLOGY RESEARCH, INC.

Gerald Mulvey Principal Investigator